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The Difference in HR Response between Track and Treadmill Running at a Pre-determined, Self-selected Pace

Marisha Corey
Brigham Young University - Provo

HEART RATE RESPONSES TO TRACK AND TREADMILL JOGGING

by

Marisha Corey

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Department of Exercise Sciences

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BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Marisha Corey

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	Pat Vehrs, Chair
Date	Jim George
Date	Iain Hunter

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Marisha Corey in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

Date	Pat Vehrs, Chair

Accepted for the Department

Ruel M. Barker
Chair, Department of Exercise Sciences

Accepted for the College

Gordon B. Lindsay, Associate Dean,
College of Health and Human Performance

ABSTRACT

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Marisha Corey

Department of Exercise Sciences

Master of Science

The purpose of this study was to determine whether or not differences exist in heart rate (HR) between jogging on the track and jogging on the treadmill at the same speed.

Twenty-four college-age (19-31 years old) male (n = 12) and female (n = 12) recreational runners volunteered to participate in this study.

Each participant performed a maximal graded exercise test (GXT) and four exercise sessions. During the first exercise session, participants completed a 1-mile steady-state jog on either the track or treadmill at a self-selected submaximal pace that could be maintained for 30 minutes. The following three exercise sessions were completed at the same pace as the first exercise session. Two of the exercise sessions were performed on the treadmill and two were performed on an indoor track. The order of the four sessions were counterbalanced. Participants were randomly assigned to an

order of sessions. Heart rate was recorded every minute and the participants were asked to give an RPE at the end of every session.

Statistical analysis revealed no significant differences in pace (mph) between the trials within the two track or two treadmill trials ($p = 0.5812$), in the HR response. Therefore, gender and trials were excluded from the final model, and the final model included only the treatment effect (track, treadmill). There was a significant treatment effect (F 1,94 = 39.126, $p < 0.0001$) indicating that significant differences in the HR responses between track and treadmill jogging at the same pace. Jogging on the treadmill elicited an average HR of 5.16 bpm (S.E. = 0.82) less than that observed while jogging on an indoor track at the same pace.

We conclude that jogging on the treadmill and track at the same, self-selected speed results in HR values that differ significantly by 5 bpm. Differences in air resistance, biomechanics, and muscle activity most likely contributed to the observed differences in HR. The results of this study are applicable to various individuals who often train or exercise on the treadmill or overground. Use of a HR monitor is recommended to determine personal responses to exercise on a treadmill and overground.

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by

Marisha Corey, M.S.

Pat R. Vehrs, Ph.D.

James D. George, Ph.D.

Iain Hunter, Ph.D.

Department of Exercise Sciences

Brigham Young University

Abstract

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Introduction

Heart rate (HR) is the most common, non-invasive measure of exercise intensity. HR responses to exercise are used in exercise testing to monitor the progression of the exercise test. Maximal exercise testing is generally performed on a treadmill. Exercise testing provides the means to control and analyze physiological variables, producing more specific, concrete data and in the case of exercise prescription, more specific exercise recommendations. HR has traditionally been used to prescribe appropriate intensities of aerobic exercise for individuals exercising to improve or maintain cardiorespiratory fitness. Based on the results of an exercise test, the American College of Sports Medicine (ACSM) recommends that exercise intensity be defined as a percentage of HR reserve or maximal HR (ACSM, 2000). Target HR zones are used to assure an appropriate and safe exercise intensity.

It is our opinion that the fitness community often assumes that target HR range recommendations based on exercise tests performed on a treadmill are also appropriate for walking, jogging or running overground. However, it is common knowledge that aerobic exercise target HR recommendations, expressed as a percent of maximal HR or HR reserve, should be specific to the mode of exercise (e.g., jogging vs cycling). If differences in HR responses to track and treadmill exercise also existed, there would be sufficient justification to modify HR recommendations for exercising on a treadmill versus overground.

Research exploring the differences in physiological responses, such as HR, to track and treadmill running is limited. Although some studies contend that the physiological responses to exercise on the treadmill are comparable to exercise on the track, there is sufficient evidence to suggest that physiological responses to track and treadmill jogging are different.

McMiken and Daniels (1976) found no statistically significant differences in maximal oxygen consumption (VO_2max) when it was measured during track or treadmill running. Their main finding was that aerobic requirements and maximum aerobic power during track running are valid when determined on the treadmill. Their results and conclusions may be questionable on the basis that the treadmill protocol used to elicit VO_2max increased percent grade incrementally between stages, whereas only speed was increased during the track protocol.

When comparing responses to treadmill and overground running, Bassett, Giese, Nagle, Ward, Raab, and Balke (1985) reported no significant differences in VO_2, HR or V_E at submaximal or maximal speeds. In a similar study, Meyer, Welter, Sharhag, and Kindermann (2003) found no differences in VO_2 while running on the treadmill and track at maximal speeds, but did report differences in submaximal VO_2, HRmax, and V_E.

Ceci and Hassmen (1991) reported that running on the treadmill at higher velocities was rated by participants as the same level of perceived physical exertion as lower velocities in the field. Nelson, Dillman, Lagasse, and Bickett (1972); Nigg, DeBoer, and Fisher (1995); and Wank, Frick, and Schmidtbleicher (1998) all reported significant biomechanical and kinematical differences when running on the treadmill compared to the track.

The primary question of this study was whether jogging at the same self-selected submaximal jogging speed on the treadmill and track elicited the same HR response.

Methods

Subjects

Twenty-four college-age (19-31 years old) male (n = 12) and female (n = 12) recreational runners volunteered to participate in this study. Participant characteristics are shown in Table 1. Participants read and signed an Informed Consent form as approved by the Institutional Review Board of Brigham Young University.

General Design

Each participant performed a maximal graded exercise test (GXT) and one exercise session on each of four different days for a total of four exercise sessions. The exercise sessions included jogging at a self-selected submaximal pace on either a treadmill or indoor track. The GXT was performed first and preceded the exercise sessions by at least 48 hours. The four exercise sessions were separated by at least 24 hours. Each participant completed his/her four exercise sessions at the same time of day. The GXTs and the treadmill exercise sessions were performed in the Exercise Physiology Lab in the Human Performance Research Center at Brigham Young University. The track exercise session was performed on the indoor track in the Smith Field House at Brigham Young University. Both facilities were temperature controlled at a constant temperature of about 22˚ C. The height and weight of each participant was measured using a standard height and weight scale.

Maximal Graded Exercise Testing

Participants were instructed to abstain from vigorous exercise for 12 hours prior to testing. Participants were also instructed to abstain from diuretic agents (i.e., caffeine), and from eating within 4 hours prior to testing. Participants were asked to arrive in the laboratory being adequately hydrated, and dressed in shorts, T-shirt, and fitness shoes.

The maximal GXT was performed on a treadmill. To facilitate the measurement of oxygen consumption (VO_2) throughout the GXT, participants were fitted with a mouthpiece and a nose clip to aid in measuring expired gases. Expired gases were measured and analyzed for the determination of ventilation (V_E), VO_2, carbon dioxide production (VCO_2) and respiratory exchange ratio (RER) using a metabolic cart. Prior to testing, the oxygen and carbon dioxide analyzers were calibrated using medical grade gases of known concentrations. The flow meter of the metabolic cart was also calibrated prior to each test using a 3.0 L syringe. Heart rate was monitored using a radiotelemetry heart rate monitor (Polar, Inc.). Rating of perceived exertion (RPE) was monitored using the Borg 15-point scale (Borg, 1970). Heart rate and VO_2 values were averaged and displayed every 15 seconds.

The maximal GXT followed a previously described protocol (George, 1996). The participant began the test by walking at a brisk pace at 0% grade for three minutes. Stage 2 of the test required three minutes of jogging at a self-selected pace at 0% grade. The treadmill speed remained constant throughout the remainder of the test; however, the grade increased 1.5% each additional minute until the participant voluntarily terminated the exercise test due to fatigue, despite verbal encouragement. Participants then performed an active cool down period of walking at a self-selected speed at 0% grade until their HR was less than 120 bpm. Participant effort was considered maximal if participants reported a rating of perceived exertion (RPE) greater than 17 (ACSM, 2000) accompanied by physical signs of exhaustion and at least two of the following three criteria (ACSM, 2000; George, 1996) were achieved:

1. a leveling off of VO_2 despite an increase in work;
2. a respiratory exchange ratio (RER) of >1.1; and
3. a maximal HR of no less than 85% of age predicted maximum heart rate (220-age).

VO_2max was defined as the highest 30-second average VO_2 value recorded during the last stage of the exercise test. Maximal HR was defined as the highest HR value recorded during the test.

Exercise Sessions

Participants performed one exercise session on each of four different days. Each of the four exercise sessions were performed at approximately the same time of day for each participant. During the first exercise session, participants completed a 1-mile steady-state jog on either the track or treadmill. Participants were instructed to self-select a constant submaximal pace that could be maintained for 30 minutes. The following three exercise sessions were completed at the same pace as the first exercise session. Two of the exercise sessions were performed on the treadmill and two were performed on an indoor track. The order of the four sessions was counterbalanced and participants were randomly assigned to an order of sessions. Participants completed pre-exercise stretching and a 5-minute warm up consisting of walking and jogging prior to each exercise session. Heart rate was monitored continually during each exercise session using a radiotelemetry heart rate monitor (Polar, Inc.). Each participant was unaware of his/her HR and jogging pace during each of the exercise sessions. RPE was also recorded using the Borg 15 point scale (Borg, 1970).

Statistical Analysis

All data were analyzed using SAS (SAS Institute Inc., Cary, NC) statistical software. A mixed model analysis was used to determine if significant differences in HR responses existed between jogging on the treadmill or track. A compound symmetric covariance structure was used to analyze HR responses between track and treadmill jogging. An unstructured covariance structure was used to analyze pace (mph) between track and treadmill jogging.

Results

The age of the participants ranged from 19-31 years of age. Females, as expected, were shorter in stature, weighed less, and had lower body mass index (BMI) and VO_2max values than their male counterparts (Table 1). All of the participants completed the maximal GXT before performing the four jogging trials. All of the GXTs were considered maximal based on the criteria described above. Data collected from each of the exercise sessions is shown in Table 2. Statistical analysis revealed no significant differences in pace (mph) between the two track or between the two treadmill exercise sessions (p = 0.5812) in either gender. Therefore, gender and trials were excluded from the final statistical model. The final model included only the treatment effect (track, treadmill). There was a significant treatment effect ($F_{1,94} = 39.126$, $p < 0.0001$) indicating that jogging on the treadmill elicited a HR that was on the average 5.16 bpm (S.E. = 0.82) less than that observed while jogging on an indoor track at the same pace.

Discussion

The most important finding of this study was treadmill jogging elicited HR responses which were on the average about 5 bpm less than jogging on an indoor track at the same pace (see Table 3). Differences in the biomechanics of jogging, muscle activity, and air resistance may explain the lower HR response to treadmill jogging. Differences in running technique have been reported between running on the treadmill and track at speeds faster than 4 m/s (8.95 mph). Compared to overground running, it has been reported that stride length shortens, stride rate increases, and the contact time of the foot to the ground is significantly decreased while jogging on the treadmill (Elliott & Blanksby, 1976; Wank et al., 1998). The decrease in contact time and increased "non-support" time may result in less muscle contraction time. The decreased contact time may be a result of the moving treadmill belt, allowing for less propulsion, which also contributes to a decrease in muscle contraction and a lower heart rate (Nigg et al., 1995). The increase in forward lean of the trunk found in overground running may be indicative of greater force being produced for propulsion (Wank et al., 1998). Muscle activity also changes when running faster than 4 m/s; for example, the vastus lateralis activity decreases during foot contact and the biceps femoris has longer duration activity during foot contact while running on the treadmill. The changes in muscle activity and muscle recruitment, caused by the biomechanical differences in running on the treadmill compared to overground, could cause a slight difference in energy demand, resulting in a slightly lower heart rate (McMahon & Greene, 1979; Wank et al., 1998).

Air resistance to jogging or running is considered to be an important factor in the differences between track and treadmill jogging. The following equation explains the influence of air resistance, or drag, on an object:

$$F_D = \tfrac{1}{2} C_D A \ell V^2$$

Where: F_D = drag force

C_D = coefficient of drag

A = frontal surface area

ℓ = air density

V = velocity of air

The most influential factor of this equation is the velocity of the air since an increase in velocity increases the drag force exponentially. During treadmill jogging, the velocity is zero; whereas, during indoor track jogging the velocity is the equal to the jogging speed. While running overground, at middle distance speeds, overcoming air resistance reportedly represented 8% of the total energy cost (Pugh, 1969). The lower HR response during treadmill jogging in this study may be attributed, in part to less air resistance.

Maximal oxygen uptake values have been found to be consistent with tests conducted on a treadmill compared to overground running. A recent study by Meyer et al. (2003), comparing maximal oxygen uptake during field exercise and treadmill running, also reported submaximal differences in V_E and VO_2. Although Meyer et al.

(2003) reported VO_2 values to be higher during treadmill running, they reported that there were no significant differences in the HR responses between track and treadmill running. The findings of Meyer et al. (2003) are contrary to the findings of this study. In the Meyer et al. (2003) study, subjects ran on the treadmill at a 5% grade to account for lack of air resistance. This difference in methods may account for discrepancies between our findings. If the subjects in the Meyer et al. (2003) study ran at level grade, HR values may have been lower than when jogging overground.

Existing evidence establishes the possibility that at submaximal jogging speeds, responses to treadmill jogging may not be as comparable to jogging overground as previously thought. The practical implications of this study can be related to various groups of individuals for whom HR response to exercise are important. Those who administer exercise programs for individuals at high risk of, have signs and symptoms of, or have known cardiovascular disease should be aware of potential differences in HR responses to exercising on the treadmill or overground. We recommend that patients be trained to monitor exercise intensity based on specific HR responses to treadmill and overground walking or jogging. It should not be assumed that HR responses to treadmill and overground exercise at the same pace are identical.

The ACSM (2000, p. 145) recommends exercising at a target HR range of 55/65 - 90% HRmax or 40/50 – 85% of HR reserve, to improve or maintain cardiorespiratory fitness. These guidelines can be used to describe an appropriate range of exercise intensity based on a maximal HR obtained during a maximal GXT. The results of this study are relevant to those individuals who are interested in performing maximal GXTs and using precise target HR zones during training to improve cardiorespiratory fitness or performance. Based on the results of this study, we recommend that these individuals base their training pace on HR response to exercise as opposed to training at predetermined running paces (min/mile). Differences in HR responses to running on the treadmill and overground are more likely to impact athletes who are training to improve performance than recreational runners. For recreational runners who do not typically perform maximal GXTs and train at specific target HRs, we recommend the occasional use of a HR monitor to become familiar with differences in HR responses to exercising on the treadmill and overground. When running on a treadmill, the runner should adjust the speed or grade to exercise at an intensity within the desired target HR zone.

The most recent recommendation from the Centers for Disease Control and the ACSM is that all Americans accumulate at least 30 minutes of moderate intensity aerobic exercise most days of the week (Pate, Pratt, & Blair, 1995). Individuals who are physically active on an almost daily basis in order to maintain weight or body composition, or to obtain other health benefits are likely to exercise overground as well as indoors on treadmills. The results of this study are relevant to the large segment of the population who exercise at community or corporate fitness centers or at home on personal treadmills. Individuals who are physically active on a regular basis should be aware of potential differences in HR responses to exercising on a treadmill or overground. This is particularly important because many of these individuals are at increased risk because of their age, bodyweight or body composition, or unknown underlying cardiovascular disease. Initial use of HR monitors is beneficial to learn safe and appropriate intensities of physical activity and exercise. Once familiar with an appropriate intensity of exercise, individuals can use ratings of perceived exertion to monitor intensity of physical activity and exercise. Occasional use of HR monitors is recommended when changes to a physical activity program are made.

Conclusion

We conclude that jogging on the treadmill and track at the same, self-selected speed results in HR values that differ significantly by 5 bpm. Differences in air resistance, biomechanics, and muscle activity most likely contribute to the observed differences in HR. The results of this study are applicable to various individuals who often train or exercise on the treadmill or overground. Use of a HR monitor is recommended to determine personal responses to exercise on a treadmill and overground.

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Table 1

Participant Characteristics

	Male (n = 12)	Female (n = 12)	Combined (N = 24)
Age (yrs)	23.2 ± 3.5	21.9 ± 1.6	22.5 ± 2.8
Weight (kg)	76.66 ± 10.02	63.33 ± 6.22*	70.00 ± 10.62
Height (cm)	179.07 ± 5.98	170.39 ± 4.65*	174.73 ± 6.86
BMI (kg/m^2)	23.87 ± 2.52	21.77 ± 1.46*	22.82 ± 2.28

BMI = Body Mass Index.

* = significant gender effect ($p < 0.05$)

Table 2

Maximal Exercise Test Results

	Male (n = 12)	Female (n = 12)	Combined (n = 24)
VO_2max	57.79 ± 4.37	49.2 ± 43.11*	53.49 ± 6.04
HRmax	187.25 ± 10.62	184.42 ± 7.28	185.83 ± 9.02
RERmax	1.26 ± 0.07	1.25 ± 0.08	1.26 ± 0.07

VO_2max = maximal volume of oxygen the body utilizes ($ml \cdot kg^{-1} \cdot min^{-1}$)
HRmax = maximum heart rate (bpm)
RERmax = maximum respiratory exchange ratio

* = significant gender effect ($p < 0.05$)

Table 3

Responses to Submaximal Track and Treadmill Jogging

	Track Jogging		Treadmill Jogging	
	Trial 1	Trial 2	Trial 1	Trial 2
Speed	7.45 ± .92	7.47 ± .93	7.42 ± .96	7.42 ± .96
HR*	167.95 ± 11.26	167.63 ± 11.43	162.93 ± 13.57	162.33 ± 11.16
%HRmax	90.39 ± 4.59	90.24 ± 5.22	87.67 ± 5.97	87.39 ± 5.03
RPE	11.85 ± 1.82	11.67 ± 1.78	12.04 ± 2.33	11.71 ± 2.31

Speed = mph
HR = heart rate (bpm)
%HRmax = percent of heart rate max
RPE = rate of perceived exertion (15 pt scale)

* = no significant difference between Trial 1 and Trial 2 of track or treadmill jogging. Significant difference ($p < 0.05$) between track and treadmill jogging HR.

Appendix A

Prospectus

Chapter 1

Introduction

Heart rate (HR) is the most common, non-invasive measure of exercise intensity. It is used in exercise testing to monitor the progression of the exercise test. Exercise testing is generally performed on the treadmill, which provides the means to control and analyze variables, producing more specific, concrete data and in the case of exercise prescription, more specific exercise recommendations. Based on the results of the exercise test, heart rate is used to prescribe appropriate and safe exercise intensity. Using a variety of available heart rate monitors, intensity of aerobic exercise can easily be monitored. Aerobic exercise programs designed to improve or maintain cardio respiratory fitness typically include walking, jogging, or running. Many people walk or jog on the streets or sidewalks but this may not always be a safe environment, nor is it conducive to changes in weather. Walking and jogging trails provide enthusiasts a safer alternative in which traffic is not a concern. Even so, unlit walking or jogging trails may not be a safe place to exercise in the evening and poor weather is still a barrier to exercise. Outdoor or indoor tracks arc also safe alternatives but have limited availability. Treadmills are a convenient and safe alternative for walkers, joggers and runners of any age or fitness level. Treadmills are available for use in homes, schools, community or corporate fitness centers, wellness centers and recreation centers. For those who prefer to walk, jog, or run on the street, walking or jogging trail, or on a track, the treadmill is a viable alternative during poor weather. It is assumed that target heart range recommendations based on exercise tests performed on a treadmill are also appropriate for walking, jogging or running over ground. It is common knowledge aerobic exercise target HR recommendations expressed as a percent of maximal HR or HR reserve should be specific to the mode of exercise (e.g. jogging vs cycling). Differences in HR response to track exercise compared to treadmill exercise would justify different HR recommendations for walking, jogging or running on a treadmill and over ground. Research exploring the differences in physiological responses, such as HR, to track and treadmill running is limited. Studies generally support the idea that physiological responses to exercise on the treadmill are comparable to exercise on the track, but research has definitely found significant differences in technique and some physiological responses (4, 6, 7). Because HR response is so often used in exercise prescription involving walking, jogging, and running, the question, is whether the exercise recommendations founded on tests performed on the treadmill elicit the same responses when applied to over ground and track walking, jogging and running.

Problem Statement

The purpose of this study is to compare HR response of treadmill and over ground jogging at pre-determined, moderate to vigorous, self-selected speeds.

Hypothesis

There is a difference in HR response to track and treadmill running at the same speed.

Null Hypothesis

There is no difference in heart rate response between track and treadmill running.

Definitions

Age predicted max HR: 220 - age = max HR

VO2 max: maximal volume of the body to uptake and utilize oxygen

HR reserve: Target HR range = ([HRmax - HRrest] x 0.60 and 0.80) + HR rest

Steady state HR: Heart rate within 6 beats per minute for more than a minute.

Assumptions

It is assumed that the self-selected speed represents a moderate to vigorous pace.
It is assumed that the data collected will represent the sample population.
It is assumed that track running represents over ground running.

Limitations

This study will not use a random sample from the target population.

Delimitations

The participants in this study will be college-age students at Brigham Young University.

The results of this study can be applied to moderate to vigorous intensity of aerobic exercise.

Significance of the study

It has been advised by many professional health organizations and the Surgeon General that every adult should accumulate at least 30 minutes of moderate to vigorous intensity physical activity on most, if not all days of the week. Heart rate is the most common, non-invasive method to monitor exercise intensity. Exercise tests used to determine an appropriate target HR range are performed on the treadmill, but the actual training often occurs on the track or in outdoors circumstances. Because current literature reports significantly different physiological and biomechanical responses to track and treadmill running, the heart rate ranges determined on the treadmill may not be directly applicable to track or outdoor running. This study is designed to compare HR responses to track and treadmill running.

Chapter 2

Review of Literature

Treadmill

The treadmill has been a common mode of exercise for many years, and is becoming more popular. Treadmills were originally used to conduct research in laboratory settings. Now treadmills are a common exercise modality in corporate and community fitness centers and homes. Treadmills allow an easy control. Treadmills offer variables such as speed and grade to vary intensity, the environment is constant and comfortable, and it is an easy means to monitor exercise response.

Maximal Treadmill and Track Running

In 1976; McMiken and Daniels compared maximal VO2 measured during track and treadmill running in eight well trained subjects. They found no statistically significant differences in VO2 max when it was measured during track or treadmill running. Their main finding was that inferences concerning aerobic requirements and maximum aerobic power are valid when determined on the treadmill (6). Results may be questioned in this conclusion on the basis that the protocols to elicit max VO2 on the treadmill were different on the track. The treadmill protocol incrementally increased % grade from stage to stage, where only speed was increased on the track protocol. In 1985 Bassett et al. completed a similar study to that of McMiken and Daniels (6). Runners performed at submaximal and maximal speeds at 0% grade and 5.7% grade on the treadmill and on a roadway. Oxygen uptake was analyzed during the last 150 meters of each run. The results from the seven subjects did not reveal any-significant differences in VO2 from treadmill to overground running at submaximal and maximal speeds (2).

Meyer et al. (2003), used portable gas analyzers to collect data throughout a maximal run. Runners performed a maximal exercise test on a track and treadmill. Speed was the only variable that increased during both tests. Meyer et al. (2003) reported that maximal VO2 was not found to be statistically significant between track and treadmill running. Interestingly, they did find significant differences in submaximal VE and VO2, and HR max (7).

The previous studies compare physiological responses to running on the track and the treadmill. Some of the conclusions include: 1) track and treadmill running elicit the same VO2 max 2) differences in physiological responses to submaximal intensities during track and treadmill jogging exist, and 3) running at a faster speed on the track is rated at the same level of perceived exertion as running at slower speeds on the treadmill. CeCi and Hassmen (1991) asked subjects to run at intensities defined by three different RPE values on both the treadmill and track. They found that the running velocities, heart rate and blood lactate measures were all higher on the track compared to the treadmill at RPE levels 11, 13, and 15. Difficulties arise in evaluating data that is as subjective as the RPE scale, but an interesting insight is derived from the data that running in the field at higher velocities is rated as the same level of perceived physical exertion as lower velocities on the treadmill.

Biomechanical Differences Between Treadmill and Track Running

From the foundation of studies that addressed the physiological differences between track and treadmill running, biomechanists were interested in the kinematic differences between the two modes of running.

Nelson (1972) observed the kinematics of experienced runners at three different speeds and grades. Results revealed that treadmill running tended to have longer periods of support, which was defined as the time the foot touched the ground until it came all the way off the ground (8). The vertical and horizontal velocities were less variable on the treadmill. They concluded that there are significant biomechanical differences on the treadmill compared to the track.

In 1995, Nigg analyzed the kinematics of overground and treadmill running of 22 subjects at two different speeds. The speeds were of a moderate intensity and a variety of different types and sizes of treadmills were used. The purpose of the study was to determine if the treadmill was a valid reproduction of human locomotion (9). After reviewing the literature, Niggs noted that the differences found in the literature may have been due to the different types of treadmills used. Niggs noted the treadmill must have a strong enough driving mechanism to minimize the energy transfer between the subject and the belt and that the visual cues and perception on the treadmill resembled that received during overground running. The results of Nigg's study showed that difference in leg kinematics became more apparent as speed increased to greater than five miles per hour. The changes that occurred from treadmill to overground were initial shoe sole angle, initial leg angle, the ankle joint inversion, and the rear foot eversion, thus concluding that the use of treadmills can both over predict and under predict aspects of ankle kinematics.

Wank (1998) placed electrodes on various joints of the body, and analyzed the EMG signals from lower limb muscles as subjects ran at three different speeds on both the treadmill and track. Five seconds were recorded for each segment. On the treadmill the subjects favored a type of running that provided them with a higher level of security. Along with differences in vertical displacement, and vertical and horizontal velocities, most subjects reduced their step length and increased stride frequency in treadmill running. Wank concluded that training on the track and treadmill were similar (16). A balance between treadmill and track running minimizes the influence of the kinematic differences when running on the track.

Heart rate responses to Treadmill and Track Running

Heart rate is a common means to monitor exercise intensity. Palpating a pulse can be taught and mastered relatively easily. Most people can palpate their carotid or radial pulse, and calculate their own heart rate (bpm). With the use of a heart rate monitor, exercise heart rates can be easily obtained. The use of heart rate monitors for personal use has increased. The increased popularity of heart rate monitors may be an indication that the public is becoming more aware of the importance of exercise. Fitness information may be found in many sources such as magazines, television, primary education, personal trainers, gyms, clubs, weight management programs, physical education facilities, health and fitness books, and published research. Most of these resources will describe similar guidelines for aerobic exercise and methods of using heart rate to monitor exercise intensity. The American College of Sports Medicine (ACSM) has published these research founded definitions and specifications. The ACSM defines physical activity as "bodily movement that is produced by the contraction of skeletal muscle that substantially increases energy expenditure (1, p.4)." Energy balance and energy expenditure are terms often used in exercise physiology and weight loss programs. The previous definition of physical activity helps us understand that this terminology includes more than just jogging or aerobic dance, it can include gardening, walking up stairs in the mall, housework, moving and many others. Because the prevalence of obesity in the American population has increased epidemically in the past quarter of a century, ACSM and many other professional organizations have focused on this critical issue and have put forth official statements that address the need for lifestyle change. One such statement was announced in 1995 by ACSM and CDC and declares "...every US adult should accumulate 30 minutes or more of moderate intensity physical activity on most, preferably all, days of the week." (1995: ACSM and CDC)

The US Surgeon General Report on Physical Activity (1986) supported the recommendation of the ACSM and CDC by stating: "Significant health benefits can be obtained by including a moderate amount of physical activity on most, if not all days of the week."

Through a modest increase in daily activity, most Americans can improve their health and quality of life. Additional health benefits can be gained through greater amounts of physical activity. People who can maintain a regular regimen of activity that is longer in duration or of more vigorous intensity are likely to derive greater benefit" (16). Both of these statements are aimed at the general population to help educate individuals in the importance of regular physical activity. The most important reason is to prevent disease and decrease the morbidity of life. Other benefits of regular physical activity include an increase in self-esteem, maintenance of muscle mass, strength, posture and flexibility.

In 1994, Sallis and Patrick made similar statements concerning the importance of physical activity for the adolescent population. They concluded that all adolescents should "...be physically active daily, or nearly every day, as part of play, games, sports, work, transportation, recreation, physical education, or planned exercise, in the content of family, school, and community activities." Also to "...engage in three or more sessions per week of activities that last 20 minutes or more at a time and that require moderate to vigorous levels of exertion (11)."

Every statement mentioned that the intensity should be moderate, or moderate to vigorous. The most common method to recommend appropriate exercise intensity includes the calculation of a target heart rate range based on a percentage of maximum heart rate (HRmax), oxygen uptake reserve (VO2 reserve) or heart rate reserve (HR reserve). ACSM recommends an intensity of exercise equivalent to: 55/65% to 90% of HRmax, 40/50% to 85% of VO2 reserve or HR reserve (1). To make use of these percentages, the patient must have a way to predict or assess their maximum heart rates or oxygen uptakes. Most often, a qualified trainer, or staff member makes these assessments with protocols that include treadmill or bike, for the purpose of making exercise recommendations and building an exercise program. Protocols include both actual max testing and submaximal testing. Submaximal testing will be used more often for exercise prescription purposes to secure safety, ease and comfort for the patient.

An equation exists that involves using age to predict maximum HR. This method involves subtracting your age from 220, the difference being your predicted maximum HR. The predictions have a lot of variability and error but are helpful in educational settings. The advantages of this method are the simplicity, efficiency and availability; sacrificing the more valid and reliable maximum bike and treadmill tests.

Londeree et al. (1995) compared the relationship between %VO_2max and %HR max during six different activities. The authors reported a fairly large discrepancy between the two predictions target HR range using a % VO_2 and %HR max for all weight bearing exercises (5).

Further research (14, 15) found that the relationship between HR reserve and VO_2 reserve was equivalent. Swain et al. documented three advantages from these findings that relate to exercise prescription and the three different ranges of exercise intensity mentioned above. First, that if heart rate is going to be implemented in the exercise prescription, the close relationship between %HR reserve and % VO_2 reserve provides a more accurate measure of intensity. Second, %VO_2 reserve provides a relative relationship for those with different intensity levels. Third, %HR reserve will be most representative of the subject's net energy expenditure (14, 15).

Strath et al. discussed that using HR as a method for assessing moderate intensity for physical activity was a strong predictor for energy expenditure (13). This concept would be understood and valued to clients as we explain energy balance and exercise intensity. HR reserve appears to be the most accurate of the three ways to assess exercise intensity.

All three fitness assessments include HR somehow in their evaluation or interpretation to an exercise recommendation. Because the measures can be assessed on the treadmill, but the actual exercise program will be performed on the track or over ground running, an argument may arise that the physiological and biomechanical differences that have been established between the two modes may cause a difference in HR, and thus not be directly applicable to over ground running.

ACSM classifies moderate intensity as 40-59% of HR and VO_2 reserve and 55-69% of HR maximum (1). It is possible that at the same speed on the track and treadmill, a subject's heart rate could be in two different categories as a result of the mode of exercise.

In conclusion, research exploring the differences in physiological differences, such as HR, in track and treadmill running is limited. Studies generally support the idea that findings on the treadmill are valid to the track, but research has definitely found significant differences in technique and some physiological responses. Because HR response is so often used in exercise prescription involving walking, jogging, and running, the question is whether the exercise recommendations founded on tests performed on the treadmill are eliciting the expected responses when applied to over ground and track walking, jogging and running.

Chapter 3

Methods

Participants

College age, male (n=12) and female (n=12), recreational runners (ages 18-29) will volunteer to participate in this study. Participants will read and sign an Informed Consent form as approved by the Institutional Review Board of Brigham Young University. All participants will complete a Physical Activity Readiness Questionnaire (PAR-Q) and have ample opportunity to address any concerns or questions about participating in the study.

Testing

Participants will perform one exercise session on each of four different days. During the first exercise session, participants will complete a 1-mile steady-state jog on either the track or treadmill at a self-selected submaximal pace that could be maintained for 30 minutes. The following three exercise sessions will be completed at the same pace as the first exercise session. Two of the exercise sessions will be performed on the treadmill and two on an indoor track. The order of the four sessions will be counterbalanced. Participants will be randomly assigned to an order of sessions. Participants will complete 5-minute warm up prior to each exercise session consisting of walking or jogging. Heart rate was monitored continually during each exercise session using a radiotelemetry heart rate monitor (Polar, Inc.) (14). RPE was also recorded using the Borg 15 point scale (3).

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Appendix A-1

CONSENT FOR PARTICIPATION IN RESEARCH

Title: Heart Rates Responses to Track and Treadmill Running.

Principle Investigator: Marisha Corey
Office in 86 SFH
Mail Box in 270 SFH
801-422-2769

Faculty Advisors: Pat Vehrs, Ph.D. (116B RB; 801-422-1626)
Iain Hunter, Ph.D. (120D RB; 801-422-1434)

1. This research is being conducted by Marisha Corey as part of her Masters Degree thesis. The purpose of this study is to determine if there are differences in the heart rate response to jogging or running on the treadmill compared to on the track.

2. As an invited volunteer participant in this research project, I will be asked to report to the Exercise Physiology Lab (121-RB) on four (4) different occasions and be subject to the following measurements, assessments, and procedures:

    a. Completion of a pre-exercise test questionnaire and measurement of height and weight.
    b. Become familiar with jogging/running at a constant pace on the track. This familiarization trial will be completed with the help of the investigator.
    c. Completion of a graded maximal exercise test on a treadmill during which I will begin exercising at a low intensity and progress in intensity in 103 minute stages. The test will be stopped when I am unable to continue exercising or if signs or symptoms appear that suggest abnormal exercise tolerance. I will be required to wear a nose clip and a mouthpiece which directs my expired air to a computerized gas analyzer. From this test maximal oxygen consumption is measured. I will be wearing a heart rate monitor during the test. Any signs and symptoms will be observed and recorded during the test. Prior to performing the graded maximal exercise test, I can exercise on the treadmill to become accustomed to the treadmill.
    d. Completion of four submaximal exercise trials. One exercise trial will be performed on each of four different days. Each testing day will be separated by at least 24 hours. During the first exercise trial I will jog 1 mile at a steady jogging pace that is approximately 75-85% of my maximal heart rate (determined from the graded maximal exercise test) on either the track or treadmill. On then ext three trials, I will jog at the same speed on the treadmill or track for a distance of 1-mile. Steady state heart rate will be recorded by the investigator. The order in which the exercise trials are performed (track or treadmill) will be randomized.

3. There may be some discomforts and risks associated with participating in this study. All possible measures to minimize any discomfort and risks will be taken. The risk of sudden death during a maximal exercise test is reported to be 0.5 deaths per 10,000 tests. During the course of any of the above mentioned exercise tests, it is possible that I may experience physical discomfort due to the stress of exercise. It is my responsibility to report any discomforts or pains that occur during or after exercise directly to the investigator. Although exercise induced discomfort is often normal, sometimes it can be an indication of underlying disease which needs further medical attention. The pre-exercise questionnaire may reveal factors that increase my risk of sudden death during exercise. If identifiable risk is apparent in my response to the questionnaire, I will not be accepted as a participant in this study. All disposable equipment used during the exercise tests will be disposed of and non disposable mouthpieces and headgears will be disinfected after each use. Heart rate monitors will be

cleaned after each use. To minimize the risk of communicable illnesses, any participants having acute or chronic illnesses will not be allowed to participate in this study.

4. As a benefit from participating in this study, I will receive results of the maximal exercise test. My results can be compared to population norms. There is no other direct benefit to me. The results may be generalized to the general population. There will be no monetary compensation offered as a result of this study.

5. The extent of my participation will include completion of each of the exercise tests of sessions described above. The maximal exercise test will take approximately 15 minutes. The length of the exercise sessions will depend on the pace which I run or jog. I will perform the tests over a one week period. My total participation time is expected to be about one and a half hours.

6. If by chance, an accident or injury were to occur during my participation, the necessary medical facilities or treatment centers will be contacted immediately. I will seek recovery of medical expenses from my personal health insurance provider for any medical treatment if deemed necessary.

7. All data gathered on myself as a participant in this study will be held confidential. I understand that data gathered from this research may be published or presented in professional meetings but my identity will remain anonymous.

8. I have been invited to participate in this research study and my participation is completely voluntary and I am in no way being coerced into participation. I also understand that I may discontinue my participation at any time without penalty or loss of benefits to which I would otherwise be entitled. New information or a change in procedures developed during the course of the study which may affect my willingness to participate will be provided to me.

9. I understand that the investigator may terminate my participation in this study due to my inability to adhere to the research protocol, unwillingness to participate in each of the exercise tests or sessions, or due to difficulty in scheduling appointments.

10. I have been given the opportunity to ask questions pertaining to the research and questions that I have asked have been answered to my satisfaction.

The person responsible for this research is Marisha Corey, a graduate student int eh Department of Physical Education. Marisha Corey can be contacted by phone at 801-422-2679 or by email at marisha@byu.edu. Dr. Pat Vehrs (116B RB; 801-422-1626) and Dr. Iain Hunter (120D RB; 801-422-1434) are the faculty advisors responsible for this project. This project ahs been reviewed by the Brigham Young University Institutional Review Board for Research with Human Participants. If you have questions you do not feel comfortable asking the researchers, you may contact Dr. Renea Beckstrand, IRB Chair, 422 SWKT, BYU, Provo UT 84602, 422-3873, renea_beckstrand@byu.edu.

I have read, understood, and received a copy of the above consent and desire of my own free will and volition to participate in this study.

________________________________ ______________
Signature of Participant Date

________________________________ ______________
Signature of Witness Date

Rating of Perceived Exertion (RPE) Scale

6
7 Very, very light
8
9 Very light
10
11 Fairly light
12
13 Somewhat Hard
14
15 Hard
16
17 Very hard
18
19 Very, very hard
20

(Borg, 1982)