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Energy Expenditure for Aerobic Exercise on a Curved Non-Motorized Treadmill Versus a Traditional Motorized Treadmill

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Abstract

Background: *While running on a traditional motorized treadmill (TMT) and a curved-deck, non-motorized treadmill (CNT) will both result in energy expenditure, it is unknown whether there is a difference in energy expenditure between the TMT and CNT. The purpose of this research was to determine if there is a significant difference in energy expenditure between running on a CNT and TMT for equivalent distances of running.*

Methods: *Nine healthy, recreationally-trained athletes (age 27.2±10.2 years) volunteered to have their effort analyzed while running on a TMT and CNT. After a familiarization period, each subject was randomly assigned to complete their first 1-mile bout on the TMT or CNT. Once completed, they were given sufficient rest before completing the second 1-mile bout on the opposing treadmill. Dependent t-test were used to test for differences between* VO_2 *(L·min*$^{-1}$*), rate of energy expenditure (REE) (kcals·min*$^{-1}$*; kcals·mile*$^{-1}$*), and heart rate (beats·min*$^{-1}$*).*

Results: *Running one mile on a CNT resulted in a greater* VO_2*(p=.0006), REE(kcals·min*$^{-1}$ *p=.0005; kcals·mile*$^{-}$*1 p=.0001) and HR (p=.005).*

Conclusion: *These findings indicate that running on a CNT results in a greater metabolic effort. The cause of this demand is yet to be conclusively determined.*

Keywords: *Treadmill, Curved, energy expenditure, calorie expenditure, heart rate.*

Introduction

Aerobic exercise is an excellent means to increase caloric expenditure, and running has been one of the most popular forms of aerobic training for more than two centuries

for reasons such as sport, health, and recreation. In the United States of America, it is estimated that over 64 million people went jogging or running in 2016 (17).

According to some experts, long-distance running was crucial in creating our current upright body form(5). Perhaps accordingly, treadmills have been used throughout the past 2000 years.In the early 19th century, the treadmill was designed and used for practical reasons such as agriculture and industrial production. Shortly after reading Dr. Kenneth Copper's text Aerobics, engineer William Staub began building exercise treadmills (20). Today, new types of aerobic machinery are still regularly introduced to the commercial fitness market.

Relying on aerobic energy systems during exercise yields a variety of benefits for overall health, some of which include increased cardiovascular health, weight loss and improved fitness levels. One of the more important variables of health is weight management, and weight loss is currently a hot topic in America. Weight concerns have been cited by Americans as a primary reason to start running (17), perhaps not surprisingly, given that National Health and Nutrition Examination Survey data report 37.9% of adults (≥20 years) are overweight and another 32.8% are obese (18). The U.S. weight loss market has recently been estimated at $66 billion (9).One of the most commonly cited barriers to consistent exercise is lack of time (1). A major topic of interest is determining which piece of aerobic exercise equipment will allow a subject to expend more energy in a relatively smaller amount of time.

A recent innovation to the modern fitness treadmill isa non-motorized, curved design treadmill. According to one manufacturer (True Form ™ Runner, Chester, Connecticut), the curved deckis designed to require the athlete to move with a mechanical motion that is thought to promote a more efficient running form. The concept that running is a skill that needs to be cultivated and learned to promote a safer and more natural running form is a belief shared by several running experts (7, 10, 12, 16).

To date, research on curved-deck non-motorized treadmills is broad yet shallow. Research has reported strong correlations between non-motorized treadmill sprinting and traditional measures of power such as the vertical jump (8) and Wingate (4). Other research comparing heart rate responses to the Rockport Walk Test performed on an indoor track versus a non-motorized treadmill found HR was higher on a non-motorized treadmill, leading to an underestimation of maximal VO_2(13). Whether these differences in heart rate extend to energy expenditure rate for 1-mile of running is not known.

Manufacturers of one type of curved non-motorized treadmill advertise that exercise on these devices results in the expenditure of approximately 30% more energy as compared to a standard motorized treadmill; however, there is limited peer-reviewed research to support this contention. In their time-based study (i.e., equivalent exercise durations) Smoliga, Hegedus and Ford (2014) found that RPE, HR, VO_2(L/min), and energy expenditure (kcal/hr) were all significantly higher on a curved treadmill (Curve XL, Woodway) than a traditional treadmill at equivalent walking and running speeds(14).These authors concluded that a curved non-motorized tread milldoes increase physiologic intensity and metabolic rate substantially above that achieved on traditional motorized treadmill. Research has reported that aerobic exercise performed on a traditional treadmill results in significantly higher rates of energy expenditure versus an Air dyne®, cross-country skiing simulator, cycle ergo meter, rowing ergo meter, stair stepper (21) and elliptical trainer (2) when performed at equivalent ratings of perceived exertion (RPEs); however, it is not known how a curved non-motorized treadmill would compare at equivalent RPEs.

To the knowledge of the researchers, no peer-reviewed published study has compared the metabolic demand (VO_2, EE and HR) of a traditional motorized treadmill (TMT) and a curved non-motorized treadmill (CNT) for a task-based protocol (i.e., running a fixed distance).Therefore, the purpose of this research was to determine if there was a significant difference in the rate of energy expenditure between equivalent distances of running on a CNT and a TMT.

Methods

Participants

Participants included nine (four males and five females) healthy, recreationally trained-participants at the University of South Carolina Aiken. All participants completed a physical assessment readiness questionnaire (PARQ) prior to engaging in testing. After explanation of all procedures, risks, and benefits, all participants signed an informed consent prior to participating in any testing. This study was approved by the University of South Carolina Institutional Review Board.

Protocol

Participants had anthropomorphic measurements recorded (age, height, weight) prior to engaging in their first one-mile treadmill bout. A 15-minute familiarization opportunity was offered to each participant to become comfortable with each piece of equipment utilized in this study before data collection began.

A True One 2400 metabolic measuring system (Parvo Medics, Sandy, UT) was used to assess VO_2 ($L•min^{-1}$), REE ($kcals•min^{-1}$) and REE ($kcals•mile^{-1}$). A Polar A300 heartrate monitor was used to monitor heart rate during each treadmill run. The motorized treadmill (TMT) was a GE T2000, and the curved non-motorized athlete-powered treadmill (CNT) was a True Form Runner ™ Enduro model (Samsara Fitness, Chester, CT).

Once the participants completed the familiarization period, they were asked to select a speed at which they felt they could comfortably completethe one-mile distance. Participants were then randomly assigned to either the CNT or TMT to complete their first one-mile treadmill bout. Once the participant completed the initial 1-mile bout, they were required to rest and recover completely prior to their second 1-mile bouton the opposing treadmill. All participants were monitored by the research staff throughout their time involved in this data collection process. After the initial 1-mile bout, treadmill speed and/or grade were reduced as participants performed an active cool down. After this, a passive cool down was completed.

Statistical Analysis

Descriptive statistics were calculated for all variables, and dependent samples t-tests were used to test for significantdifferences in average HR, VO_2, and REE between the CNT and TMT. Statistical analyses were performed using SPSS (Version 24.0. Armonk, NY: IBM Corp) with an a priori level of significance set at $p < 0.05$.

Results

Table 1. *Participant anthropometrics*

Characteristic	Mean ± SD
Age (yrs)	27.2 ± 10.2
Height (cm)	160.2 ± 17.3
Weight (kg)	79.1 ± 10.3

Statistical analyses revealed significant differences between the CNT and TMT for all variables for an equivalent distance of running. (Table 2)

Table 2. *Comparison of motorized and non-motorized treadmills for the variables of interest*

Variable	Motorized	Non-motorized	p value
VO_2 ($L•min^{-1}$)	1.6±0.9	2.2±1.1	0.0006
REE ($kcals•min^{-1}$)	7.9±4.6	10.9±5.4	0.0005
REE ($kcals•mile^{-1}$)	98.4±35.4	144.8±32.2	0.0001
HR ($beats•min^{-1}$)	152.0±29.3	164.9±23.3	0.005

VO_2 - volume of oxygen; REE – rate of energy expenditure; HR – heart rate

Discussion

A one-mile running effort at a self-selected speed on a CNT required a significantly higher VO_2, EE, and HR compared to a TMT. Based on these results, the CNT is more physiologically demanding. This conclusion supports previous research which found the physiological demand of locomotion on a CNT to be greater than that of a TMT (3, 6, 11, 15). The results suggest that although a TMT has been the most efficient tool for calorie expenditure(19), the CNT is an improved method of energy expenditure because the demand placed on the individual's body is greater. These differences may be attributable to the unique design of the arced treadmill that requires different biomechanics (6)as well as additional work to propel the non-motorized belt versus to keep up with a moving belt (14).

In the present study, VO_2 ($L·min^{-1}$) was 37.5% higher, and heart rate was 8% higher. Running 1-mile on a CNT resulted in the expenditure of 144.8 kcals, a value 38.2% greater than that achieved running the same distance on a TMT (98.4 kcals). Similarly, the rate of energy expenditure (kcal/min) was 31.9% higher on the CNT. The results found in the present study support those from a previous study which reported that aerobic exercise on a CNT resulted in the expenditure of 36.1% more calories than the TMT(11).These results support the fact that a curved non-motorized treadmill places a greater physiological demand on the body's systems during sub-maximal aerobic exercise. These results are important to consider when prescribing fitness programs.

A component to the current study that is different from previously reported research is a task-oriented design compared to time-oriented designs(11, 15). The present study focused on a task priority protocol (i.e., run 1 mile). Considered collectively, these results indicate that a curved, non-motorized treadmill results in greater physiological demand whether one compares equivalent task- or time-based protocols.

These finding suggest that a CNT is an ideal aerobic machine for maximal calorie expenditure during sub maximal aerobic exercise. Variables tested in this study were $VO_{2,}$ heart rate and energy expenditure. In each category, the CNT resulted in a higher demand than the TMT. This relatively novel aerobic exercise machines present many exciting opportunities for future research including an examination of energy expenditure values between a CNT and road running, gait differences between curved and traditional treadmills, injury rates and standardization of non-motorized treadmill resistance values.

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