International Journal of EXERCISE SCIENCE

Original Research

Physiological Responses to Speed-Matched Running on Non-Motorized Assault AirRunner versus Traditional Treadmills in Active Females: A Pilot Study

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ABSTRACT

International Journal of Exercise Science 15(4): 1262-1273, 2022. Treadmills are utilized as a training tool to improve aerobic fitness, but precise understanding of intensity and the corresponding physiological strain is critical for optimizing exercise prescription and associated adaptations. Running on non-motorized, curved treadmills may result in greater oxygen uptake (VO_2), increased heart rate (HR), and increased rating of perceived exertion (RPE) compared to traditional motorized treadmills. The purpose of this study was to investigate the physiological responses on non-motorized versus traditional motorized treadmills during speed-matched running. Participants were 4 college-aged, recreationally active females. HR, VO_2, respiratory exchange ratio (RER), and RPE were monitored during 3 speed-matched stages of incremental exercise in two conditions: the non-motorized Assault AirRunner and a traditional motorized treadmill, as well as for 5 minutes post-exercise. VO_2, RER, and HR were greater in the Assault condition (ES_{VO2} = 0.998, ES_{RER} = 0.839, ES_{HR} = 0.972, $p < 0.05$). While not significant between groups, RPE showed a greater increase with increasing speeds in the Assault condition (ES = 0.728), as did RER (ES = 0.800, $p < 0.05$). Cumulative excess-post exercise oxygen consumption (EPOC) during a five-minute period post-exercise was also greater in the Assault condition, and HR and RER remained higher five minutes post-exercise in the Assault condition (ES_{EPOC} = 0.738, ES_{HR} = 1.600, ES_{RER} = 2.075, $p < 0.05$). The Assault AirRunner elicited greater physiological responses (VO_2, carbohydrate usage, and HR) in response to speed-matched running in comparison to a traditional motorized treadmill in active college-aged females. Collectively, aerobic exercise conducted on the Assault AirRunner has a greater physiological and perceived intensity and need to be taken into consideration when designing and implementing training programs or testing.

KEY WORDS: Metabolism, energy cost, women, motorized, training

INTRODUCTION

Treadmills are used as a key training tool to improve aerobic fitness in a wide variety of populations, thus understanding appropriate intensities and their physiological cost is an important factor when prescribing treadmill exercise to improve aerobic fitness. Oxygen consumption (VO_2) is an indirect measure of energy expenditure and can be used to determine the energy cost of exercise, or the number of calories burned during treadmill running. When the VO_2 is compared with carbon dioxide production (VCO_2), the resulting respiratory exchange ratio (RER) is used to estimate relative substrate utilization, specifically carbohydrate versus fat utilization when running (18). These variables, along with heart rate (HR) indicate the physiological intensity of exercise, while rating of perceived exertion (RPE) indicates the psychologically perceived intensity of treadmill running (19). Upon completion of treadmill running, excess post-exercise oxygen consumption (EPOC) can also be an indication of the physiological intensity of an acute exercise bout, as oxygen consumption will remain elevated above baseline in proportion to the intensity of the exercise bout (17).

Recently, a non-motorized curved treadmill, the Assault AirRunner has been purported to "burn more calories than the average motorized version" (2). These treadmills consist of a concave belt that is propelled by the runner, allowing them to subconsciously select their pace and quickly accelerate or decelerate, more closely resembling outdoor running (6, 12). Previous research has shown that running on non-motorized treadmills results in greater oxygen uptake, increased heart rate, and increased rating of perceived exertion in comparison to traditional motorized treadmills, but the majority of these studies have used other brands of non-motorized, curved treadmills, with various models of the Woodway Curve being the most common (3, 6, 9, 12, 14). While the Assault AirRunner consists of similar technology, no research has yet been published utilizing this model. Furthermore, participants for these limited number of studies were often exclusively conducted on male participants or had a mixture of males and females and lacked between-sex comparisons, so research specifically examining how females respond to aerobic exercise on non-motorized treadmills is limited (14, 19). While not utilizing non-motorized treadmills Li et al. found increased energy expenditure and carbohydrate utilization during overground running, compared to treadmill running, at higher speeds in middle-aged women (8), so it is plausible to hypothesize similar results comparing motorized to non-motorized treadmills. Further, study of the physiological responses in the post-exercise period upon completion of non-motorized and traditional motorized treadmill running is lacking.

This study took a novel approach by examining the physiological responses to speed-matched running on two different treadmill types specifically in recreationally-active college-aged females, due to the limited information regarding physiological responses to exercise on non-motorized treadmills in females or in the post-exercise period. In addition, this pilot study may provide evidence supporting which treadmill type may be best suited given an individual's exercise goals and effect sizes to support further research. The purpose of this study was to examine the physiological responses to speed-matched running on a non-motorized Assault AirRunner versus traditional motorized treadmill for active college-aged females. It was hypothesized that the Assault non-motorized treadmill would result in greater HR, VO_2, RER, and RPE than speed-matched running on a traditional treadmill in active college-aged females, which would elicit higher a EPOC and associated physiological responses.

METHODS

Participants
In this pilot study, participants for this study were four recreationally active college-aged females. The participants were recruited at Skidmore College by word of mouth. Recreationally active inclusion criteria included running at least two days per week for at least 30 minutes per session at a moderate to vigorous intensity, regularly during the fall semester, as identified by the participants. Exclusion criteria included participating on an in-season varsity athletic team or having any lower extremity injuries as screened for using Medical History and Exercise Questionnaires. Additional exclusion criteria included any cardiac, respiratory, and/or metabolic diseases, and participants must be non-smokers. All participants provided written informed consent prior to participation in this study. The study was conducted at Skidmore College in Saratoga Springs, NY and was approved by the Skidmore College Institutional Review Board (IRB#1810-755). This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (10), and with the ethical standards of the most recent revisions to the Declaration of Helsinki.

Protocol
A repeated-measures, counterbalanced experimental design was used to compare the physiological responses to speed-matched running on Assault brand non-motorized versus traditional treadmills in recreationally active, college-aged females. Three visits were conducted for each participant: first, a familiarization trial (during which no data was collected other than height and weight), then two separate visits to run on either the Assault AirRunner or the traditional treadmill (Figure 1). During the familiarization trial, participants filled out an informed consent, Physical Activity Readiness Questionnaire (PAR-Q), and a Medical History and Exercise Questionnaire to ensure that participants met inclusion criteria. Height and weight were then measured. Participants then ran for 3 minutes at 3, 5, and 7 mph on each type of treadmill in order to become familiarized with running on the different treadmill types. They were also instructed to complete a food log during the 24 hours leading up to their first experimental trial. Participants were not restricted in what they could consume but had to follow the same 24-hour diet before both treadmill trials and were required to fast overnight leading up to the testing session.

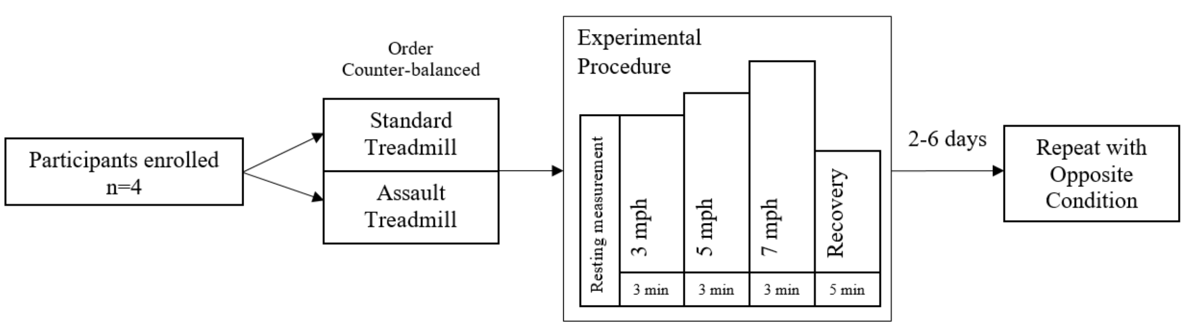

Figure 1. Experimental Overview.

All trials took place at least 48 hours apart, but the experimental trials were performed within 7 days of each other (11). The order of the treadmill condition trials was counterbalanced, alternating for each participant based on order of testing. At experimental trials, seated resting values for VO_2, RER, and HR were monitored for at least five minutes with data recorded once values had stabilized. The exercise bout was 9 minutes total, walking or running for 3 minutes at 3, 5, and 7 mph respectively. These speeds were chosen to represent a moderate-intensity walk (3 mph), and a vigorous-intensity jog (5 mph), and a vigorous-intensity run (7 mph) (1). Speed was adjusted by a member of the research team on the standard treadmill. On the Assault AirRunner, researchers monitored actual speed and gave participants verbal coaching consisting of "speed up," "slow down," or "good speed" in order to maintain proper speed. VO_2 and RER were recorded every 30 seconds, while HR and RPE were recorded every minute. After the exercise was completed, participants were immediately seated for 5 minutes while post-exercise values for VO_2, RER, and HR were measured; the VO_2 values were used to determine EPOC.

Relative Oxygen Consumption (VO_2) (mL/kg*min) and Respiratory Exchange Ratio (RER) were reported at baseline, during all 3 stages of exercise, and during the 5-minute post-exercise recovery period by a ParvoMedics TrueOne 2400 metabolic cart, which has been shown to be a reliable and valid instrument for assessing oxygen consumption and carbon dioxide production (4). These values were recorded in the final minute of baseline monitoring and every 30 seconds while running and during recovery.

Heart Rate (HR) was assessed using a Polar H7 heart rate monitor with chest strap that reported to the Polar Beat iPhone app (Version 2.6.3) via Bluetooth at baseline, during all 3 stages of exercise, and during the 5-minute recovery period. Values were recorded in the final minute of baseline monitoring and every minute while running and during recovery.

Rating of Perceived Exertion (RPE) was provided by the participant on a 1-10 scale every minute during exercise. The RPE scale is an effective method of quantifying perceived exercise intensity through a wide variety of exercise types (5). Participants were shown a chart with the RPE scale, then ratings were provided by the participant as they held up a number with their fingers to indicate their RPE on the 1-10 scale.

Statistical Analysis

To ensure baseline values were consistent amongst conditions, paired t-tests were performed on resting HR, VO_2, and RER values. Values for HR, VO_2, RER, and RPE during exercise were analyzed using a within-subjects 2 x 3 (Condition x speed) Analysis of Variance (ANOVA). Effect size (ES) was determined by the partial eta squared value (0.01 = small, 0.06 = medium, 0.14 = large). If missing data occurred, mean substitution was used to fill in missing points in order to complete the analysis. Paired t-tests were run for all post-exercise data between conditions at five-minutes post-exercise using paired t-tests, and ES was determined using Hedges' g (small = 0.2, medium = 0.5, large = 0.8). To compare EPOC, the area under each VO_2 curve from data recorded five minutes post-exercise was calculated and compared using a paired t-test. All data were analyzed using IBM SPSS Statistics software version 25 (IBM, Armonk, New York, USA). The level of significance was established at $p < 0.05$. As this is a pilot study, data are presented as means ± standard error.

RESULTS

A total of four recreationally active college-aged females (21 ± 0.4 yrs, 165 ± 1.4 cm, 58.9 ± 1.6 kg) completed this study. No differences were seen in baseline values for HR ($p = 0.351$), VO_2 ($p = 0.462$), or RER ($p = 0.334$) between the two treadmill conditions (Table 2). One participant failed to complete the exercise trial in the Assault condition within the final 30 seconds of the 9-minute exercise bout.

Resting HR did not differ between treadmill conditions (73 ± 4 vs 79 ± 8 bpm, traditional vs. Assault). HR increased with speed (ES = 0.984, $p < 0.001$) and was significantly greater in the Assault condition during exercise (ES = 0.972, $p = 0.002$), with an average difference of 18 bpm (± 1) between conditions (Figure 2). There was also a large (ES = 0.357) but statistically insignificant ($p = 0.266$) interaction effect between speed and condition for HR. HR in the Assault condition also remained an average of 9 bpm higher than in the traditional condition at five minutes post-exercise (ES = 1.600, $p = 0.003$) (Figure 2).

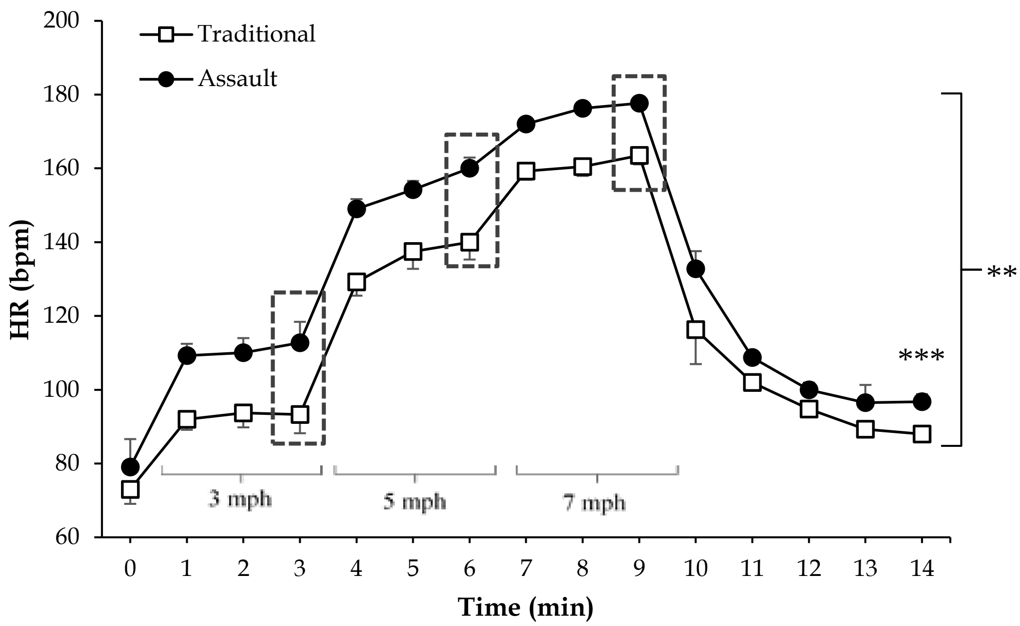

Figure 2. Mean ± standard error. Heart Rate (HR, in beats per minute, bpm) response to exercise on Traditional and Assault AirRunner treadmills at 3, 5, and 7 mph in young active females ($n = 4$). Dashed box denotes last time point in each stage, used for data analysis. **$p < 0.05$ within-subjects effect for condition, ***$p < 0.05$ difference in HR 5 min post-exercise.

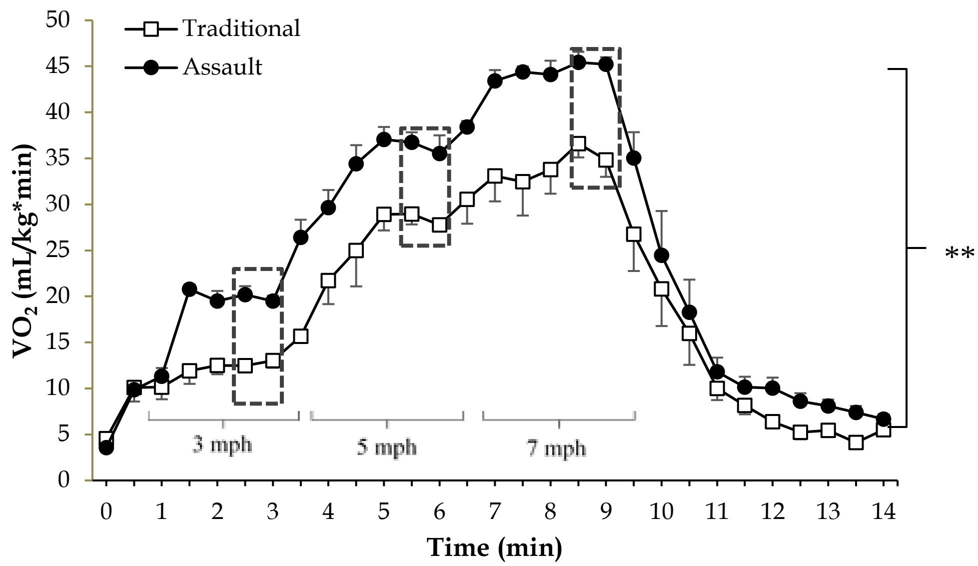

Figure 3. VO_2 response to exercise on Traditional and Assault AirRunner treadmills in young active females (n = 4). Dashed box denotes last minute in each stage, points used for data analysis. **$p < 0.05$ within-subjects effect for condition.

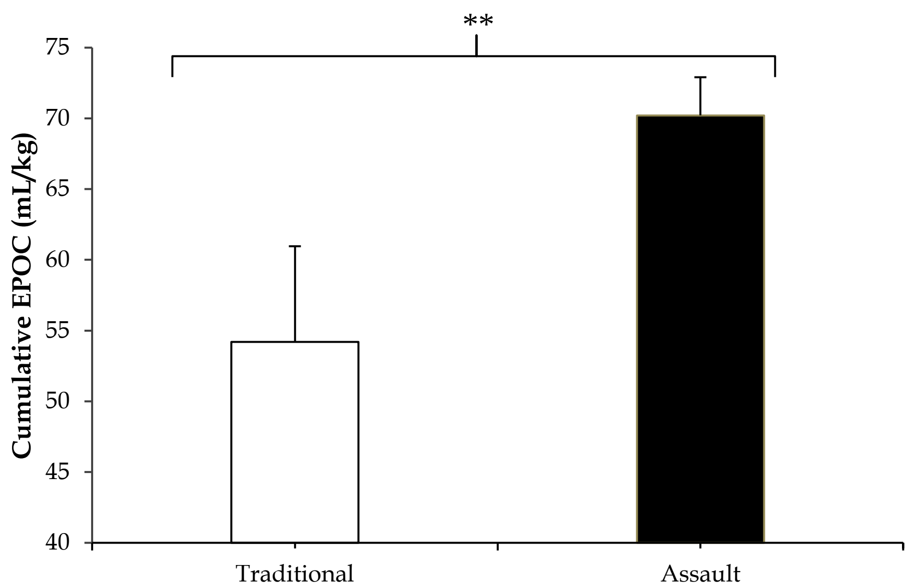

Figure 4. Cumulative EPOC during 5 min of rest following exercise trial in Traditional and Assault AirRunner conditions in young active women (n = 4). **$p < 0.05$ significant difference between conditions.

Resting VO_2 was not different between treadmill conditions (4.6 ± 0.9 vs 3.6 ± 0.6 ml/kg*min, traditional vs. Assault). VO_2 increased with speed (ES = 0.995, $p < 0.001$) and was significantly greater in the Assault condition by 8.2 mL/kg/min during exercise (ES = 0.998, $p < 0.001$) (Figure 3). There was a large (ES = 0.187) but statistically insignificant ($p = 0.538$) interaction effect between speed and condition for VO_2. EPOC was significantly greater in the Assault condition compared to traditional (average difference of 16.0 ± 9.7 mL/kg, ES = 1.131, $p = 0.045$) (Figure 4). There was a large effect for VO_2 being higher in the Assault compared to traditional condition at five minutes post exercise (ES = 1.494), but this did not reach statistical significance ($p = 0.099$).

Resting RER was not different between treadmill conditions (0.91 ± 0.05 vs 0.84 ± 0.03, traditional vs. Assault). For RER, there was a large and significant interaction effect between condition and speed, where RER increased more both with speed and after exercise in the Assault condition compared to the traditional treadmill (ES = 0.8, p = 0.008) (Figure 5). As hypothesized, RER increased with speed (ES = 0.960, $p < 0.001$) and was significantly greater in the Assault condition by 0.09 (± 0.02) VCO_2:VO_2 (ES = 0.839, p = 0.029) (Figure 5). RER in the Assault condition also remained higher that traditional (0.36 ± 0.11 VCO_2:VO_2) at five minutes post-exercise (ES = 2.075, p = 0.006) (Figure 5).

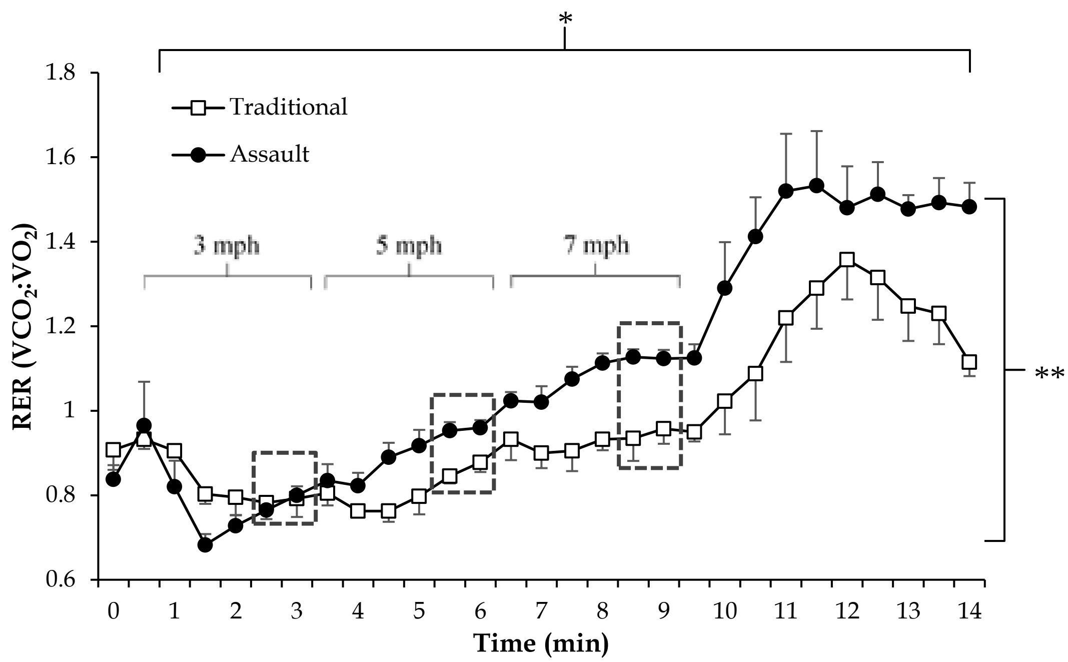

Figure 5. RER response to exercise on Traditional and Assault treadmills in young active women (n = 4). Dashed box denotes last minute in each stage, points used for data analysis. *$p < 0.05$ interaction effect between condition and speed. **$p < 0.05$ within-subjects effect for condition. ***$p < 0.05$ difference in RER 5 min post-exercise.

There was a large and significant interaction effect between condition and speed for RPE, with a greater increase in the Assault condition compared to traditional (ES = 0.728, p = 0.020) (Figure 6). RPE increased with speed (ES = 0.929, $p < 0.001$), but there was no significant difference in RPE between conditions (ES = 0.508, p = 0.176) (Figure 6).

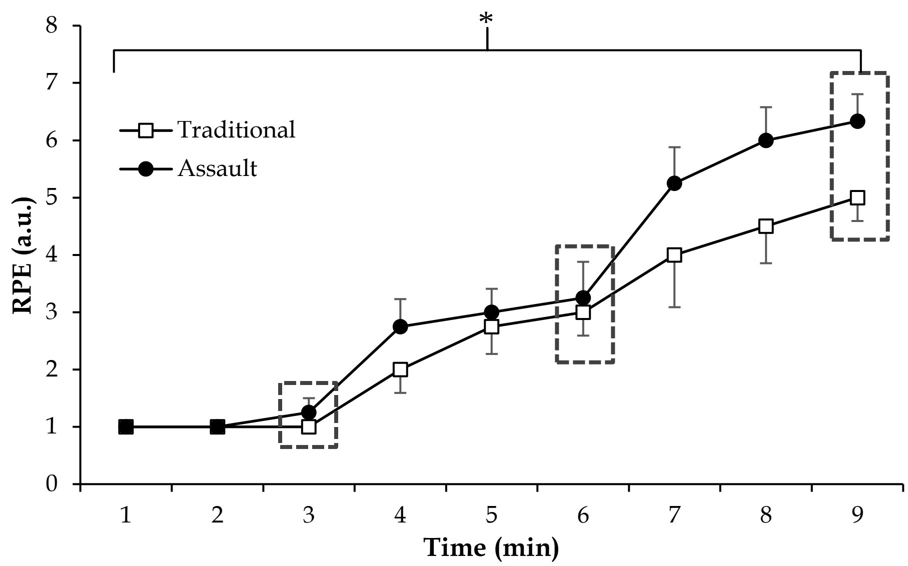

Figure 6. RPE in response to exercise on Traditional and Assault treadmills at 3, 5, and 7 mph in young active women (*n* = 4). Dashed box denotes last time point in each stage, used for data analysis. *$p < 0.05$ interaction effect between condition and time.

DISCUSSION

The purpose of this study was to compare the physiological responses during speed-matched running on Assault brand non-motorized and traditional treadmills in active female college students. Overall, exercising on the Assault AirRunner prompted increased cardiorespiratory and metabolic responses in comparison to a standard motorized treadmill when matched for speed. An increased cardiorespiratory response was seen when participants ran on the Assault AirRunner in comparison to the traditional treadmill with significantly higher HR and VO_2 values in the Assault condition at all three running speeds. Additionally, EPOC was significantly higher following exercise on the Assault brand treadmill. When examining RER, increases were seen over time, and values were significantly greater at each speed and post-exercise in the Assault condition, suggesting greater reliance on carbohydrates. RPE was also shown to increase significantly more over time in the Assault condition, but was not significant between conditions at each speed. Collectively, these findings indicate that running on a non-motorized treadmill increases the physiological cost, for the first time in women, which extends to the post-exercise period.

Multiple studies found that VO_2 increased when running on a non-motorized treadmill, again demonstrated in almost exclusively male participants using other models of treadmills (15, 16, 19). Wee et al. found that oxygen uptake was significantly greater when running at three velocities on a non-motorized treadmill in comparison to both a traditional motorized treadmill and to running on an indoor track (19). Similarly, Snyder et al. found that VO_2, as well as the rate of ventilation and respiratory ratio, were significantly greater while walking on a non-motorized treadmill at three velocities in comparison to a traditional motorized treadmill (15). The findings in the current study are in alignment with previous findings, as VO_2 was significantly greater in the Assault brand non-motorized treadmill condition at all three running speeds, despite speed matching. No prior studies, to date, have assessed EPOC during non-motorized treadmill running, to this end, in the present study a significantly greater EPOC was observed in the non-motorized Assault condition.

Previous studies have shown that walking or running on a non-motorized treadmill is associated with increased HR (13, 15, 19). Some studies compared HR while exercising on a non-motorized treadmill to a traditional motorized treadmill (15, 19) while others compared to exercising on an indoor track (13). Additionally, similar results were seen in a study conducted by Stevens et al. (16). In that study, there was no significant difference in HR between conditions running on a non-motorized treadmill and on an outdoor track, but participants did have significantly lower running speeds on the non-motorized treadmill, indicating that if speed-matched running had been achieved between these two conditions it may have resulted in a higher HR during the non-motorized treadmill condition (16). Those previous findings are in alignment with the results of the current study, which showed significant higher HRs at all three running speeds on the Assault AirRunner in comparison to a traditional motorized treadmill, indicating greater cardiac strain to support the increased metabolic cost.

When examining RER, Snyder et al. found that walking at three different speeds on a non-motorized treadmill was associated with increased RER in comparison to a traditional motorized treadmill (15), similar to how RER was shown to be significantly higher in the Assault condition in the present study. Other studies examined metabolic responses in exercise using other variables, including metabolic intensity and blood lactate concentration (14, 19). These studies agreed that there are greater metabolic demands, particularly increased carbohydrate utilization, placed on the body during aerobic exercise on a non-motorized treadmill in comparison to traditional motorized treadmills (14, 19). Coaches, athletes and other practitioners should be aware of the greater metabolic perturbation and associated reliance on carbohydrates when designing or conducting training sessions, as assumptions about metabolic similarity between treadmill modalities are untrue and need to be recognized.

Many studies have found that RPE was significantly greater during running exercise on non-motorized treadmills (14, 8, 16, 19). This was also true when comparing speed-matched running on non-motorized treadmills in comparison to traditional motorized treadmills (14, 15, 19), indoor tracks (19), and outdoor tracks (16). Those prior findings are in alignment with the results of the current study that found that RPE significantly increased over time in the Assault condition. Furthermore, in this study, one participant failed to complete the Assault condition within the final 30 seconds of the trial. This most likely reflects the increased cardiorespiratory and metabolic demand indicated by the other results of this study, contributing to a greater perception of effort when compared to speed matched motorized treadmill running.

Previous studies utilized either recreationally active individuals (3, 7, 9), trained athletes (6, 12), or a combination of both (14), and greater physiological intensity during the non-motorized conditions was observed in all populations. In the present study, participants were recreational runners, but were unfamiliar with using a non-motorized treadmill prior to the study. It is possible that the effect size may be smaller in populations familiar with a non-motorized treadmill or sedentary populations to whom both kinds of treadmills are unfamiliar. Furthermore, the vast majority of previous literature utilized the Woodway Curve non-motorized treadmill (3, 6, 9, 12, 14). Similar results were seen in this study using the Assault AirRunner, but it is possible that different models elicit different responses that were not detectable due to difference in populations and exercise protocols.

Of the studies consisting of both male and female participants (3, 6, 7, 9, 14), both sexes showed similar responses to motorized versus non-motorized treadmills. Edwards et al. studied both men and women, and while between-sex differences were either *trivial* or *unclear*, they did find that running economy on a non-motorized treadmill decreased with decreasing bodyweight, likely due to the increased relative force needed to propel the belt (6). This may mean that the physiologic effect of a non-motorized treadmill is greater in females with a lower bodyweight.

This pilot study is not without limitations. This study had a small sample size and did not control for the participants' menstrual cycles or oral contraceptive use given scheduling and recruitment constraints. However, given the magnitude of differences between conditions, menstrual cycle phase is unlikely to account for such differences, and the effects noted herein could be used to generate further research. Additionally, one main limitation of this study was that the participants had the added stress of controlling their running speed during the Assault condition trials as this treadmill is non-motorized and therefore requires attention in order to maintain a fairly constant speed, though participants were familiarized before the experimental trials to minimize such an effect. Regardless, the results of this study are promising and warrant future research to further examine cardiorespiratory and metabolic responses in larger sample sizes as well as in varying demographics such as sedentary persons, younger or older participants.

Conclusion: This study aimed to investigate the cardiorespiratory and metabolic responses to speed-matched running on Assault brand non-motorized and traditional motorized treadmills in active college-aged females. The results of this study supported the original hypothesis that the Assault brand treadmill would trigger greater cardiorespiratory and metabolic responses during exercise. These results would suggest that an individual looking for a more challenging aerobic workout may gain benefit from running on an Assault AirRunner.

ACKNOWLEDGEMENTS

The authors would like to thank the participants and the athletic department for making this study possible.

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