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RESEARCH ARTICLE

Respiratory exchange ratio in aerobic exercise on treadmill versus cycle ergometer at similar perceived exertion

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ABSTRACT

Background: Treadmill (TM) and cycle ergometer (CE) are the most commonly used indoor machines for aerobic exercise (AE). Previous studies have indicated that TM causes higher fat oxidation than CE AE; however, data from the Indian subcontinent are lacking regarding the same. Accumulation of visceral fat leads to various cardiovascular and metabolic disorders, and hence, AE modality that causes higher fat oxidation could prove more beneficial in improving health-related quality of life. **Aims and Objectives:** The aim of this study is to compare cardiovascular response and respiratory exchange ratio (RER) in TM and CE AE by moderately active males at similar ratings of perceived exertion (RPE). **Materials and Methods:** In the present experimental study, sixteen males with normal body mass index were involved to perform 30 min of continuous moderate intensity AE on TM and CE at RPE of 13. Systolic blood pressure (SBP) and diastolic blood pressure (DBP), heart rate (HR), and pulse pressure (PP) were analyzed just before and after the exercise trial. RER was estimated during the last 2 min of exercise. Paired *t*-test was applied to compare the means, and $P < 0.05$ was considered statistically significant. **Results:** HR after TM (136 ± 10) tended ($P = 0.063$) to be higher than CE (132 ± 9), while changes in SBP, DBP, and PP were non-significant. RER was non-significantly ($P = 0.148$) higher in CE (0.89 ± 0.05) than TM (0.91 ± 0.06). Oxygen consumption was significantly ($P = 0.049$) higher in TM (1.11 ± 0.17 L/min) than CE (1.03 ± 0.16 L/min). **Conclusion:** TM caused significantly higher energy consumption with non-significantly higher HR and fat oxidation than CE AE at RPE of 13.

KEY WORDS: Cardiovascular Response; Cycling; Substrate Utilization; Walking

INTRODUCTION

Global physical activity trend shows that about one-third of the adult population is physically inactive.[1] Pederson proposed the "diseasome of physical inactivity" hypothesis which states that the visceral fat accumulation due to physical inactivity causes activation of various inflammatory pathways leading to the development of various cardiovascular and metabolic disorders.[2] Increasing fat oxidation through exercise might prevent the "diseasome of physical inactivity."

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Aerobic exercise (AE) is one of the best forms of physical activity to burn calories and lose weight.[3] Among different available devices, cycle ergometer (CE) and treadmill (TM) are the most common modalities of indoor AE.[4]

Few previous studies have reported a higher fat oxidation in walking on TM as compared to pedaling on CE when performed by obese women,[5] obese adolescent,[6] children,[7] and moderately trained males.[8] Similar results were reported on comparing running with cycling done by moderately trained males[8,9] and females,[9] male triatheletes,[10] and endurance atheletes.[11] Although both TM and CE have advantages and disadvantages,[12] but for fat oxidation, TM might be more beneficial than CE at equivalent AE intensity. The exercise intensity in these studies was estimated by the variables such as percentage of maximum oxygen uptake (% VO_{2max}) and work done or heart rate (HR) (% HR_{max}) that requires expensive laboratory equipment and is not a practical approach for developing countries as these instruments are not available to the mass population.

King *et al*.[13] reported that endurance exercise on TM caused higher fat oxidation than CE in active women at similar perceived exertion. At home or in gyms, an individual exercises on the basis of their perceived exertion rather than the % VO_{2max} or % HR_{max}, and hence, comparing fat oxidation at similar perceived exertion might be a better approach. Borg's devised a psychophysiological approach of rating the perceived exertion on a numerical scale.[14] Despite being a subjective scale, Borg's rating of perceived exertion (RPE) 6–20 scale has a strong correlation with objective parameters of gauging exercise intensity.[15]

The amount of carbon dioxide (VCO_2) produced and oxygen (VO_2) used during exercise depends on the types of substrates being used for energy production, and their ratio (VO_2/VCO_2) is known as respiratory exchange ratio (RER). The value of RER is directly proportional to the percentage of carbohydrate and inversely proportional to the percentage of fat being utilized for energy production.[16,17]

In author's best knowledge, none of the studies from India has reported the substrate utilization or RER for young males. Hence, the present study was designed to compare TM with CE AE for cardiovascular response and substrate utilization at similar RPE in moderately active young males.

MATERIALS AND METHODS

The present experimental study was conducted in the Exercise Physiology Laboratory of King George's Medical University, Uttar Pradesh, Lucknow, after approval by the Institutional Ethical Committee. All participants provided an informed consent after adequate explanation of the objectives, procedures, potential risks or discomfort, and benefits of the study.

Sample Size Determination

The sample size (n) was calculated by the G*Power Software v3.1.9.2 for Windows[18] on the basis of the results reported by a previous study,[13] in which RER during CE compared to TM at the RPE equal to 13 was 0.95 ± 0.03 and 0.89 ± 0.05, respectively. At 95% power (5% β error) and 5% significance level (α error), the sample size calculated was 10 when a two-tailed paired *t*-test was used to compare the means of two dependent groups. However, 16 subjects were involved in the present study who fulfilled all inclusion and exclusion criteria.

Inclusion Criteria

Apparently healthy individuals based on the history, general, and systemic examination were involved in the study. As the sample size of the study is not large, hence only males having a normal body mass index (BMI) (BMI = 18.5–22.9 kg/m^2)[19] and 18–25 years of age were included to maintain the homogeneity of data. Participants were "moderately active" as assessed by "general practice physical activity questionnaire" which is a validated screening tool to assess adult physical activity levels of adults (16–74 years).[20]

Exclusion Criteria

Known history of any disease, or any abnormality detected during the physical examination that might have adversely affected the participant's health or study results were the exclusion criteria. Furthermore, if a participant answered positively, i.e., "yes" to any of the questions in "physical activity readiness questionnaire" by Canadian society for exercise physiology,[21] they were excluded from the study.

Training Protocol

Each participant did AE on CE and TM. Excel sheet randomiztion method was used to decide the mode of exercise (CE or TM) that a participant had to undergo first - followed by a rest period of 15 days - thereafter, participants performed the other modality of exercise. Participants were told to refrain from any strenuous muscular activity during the study period. The data from all participants were later pooled to form two groups, namely CE and TM. Training protocol was divided into (a) familiarization cum training sessions and (b) Last exercise session or experimental trial, on which parameters were recorded.

Familiarization Sessions

Three familiarization sessions were done 48 h apart before each experimental trial. A magnetic resistance CE (Upright bike 745, Pro Bodyline Fitness, Rajasthan, India) and a motorized TM (model no. 950, Pro Bodyline Fitness, Rajasthan, India) were used for exercise. Influence of circadian rhythm on the cardiovascular variables was eliminated by scheduling all the exercise sessions at the same time of the day (between 2 PM and 4 PM). Participants were instructed to wear non-restrictive, comfortable clothing before coming to the exercise physiology laboratory.

Participants were made aware of the exercise protocol and Borg's RPE 6–20 scale. They were asked to walk on TM or pedal CE at RPE of 13 that corresponds to the recommended[22,23] moderate-intensity exercise.[23] They were allowed to change the speed of CE (set at magnetic resistance level 4) and TM (manually inclined at 5% grade or 3° slope) to attain the desired exertion level. First familiarization session started with 10 min of exercise which was increased by 10 min on subsequent familiarization sessions.

Experimental Trial

Participants were instructed to write their 24 h diet before the first experimental trial so that they replicate almost similar diet before the second experimental trial. Participants did recommended 30 min of moderate-intensity AE[22,23] after at least 6 h of fasting and 24 h of abstinence from the substance abuse (such as smoking, tobacco, alcohol, and excessive caffeine intake) of any form. Participants were asked to maintain approximately the same speed on TM and CE throughout the exercise as for estimation RER steady-state condition must be present.[24] HR of the participants was monitored continuously during the exercise sessions by "Omron pulse oximeter MD300C20" to get an objective measure of exercise intensity during the workout.

Study Parameters

The following study parameters were recorded:

a. Anthropometric assessment: The same investigator performed all anthropometric measurements. Body weight was measured with the subjects wearing light clothing and no shoes to the nearest 0.1 kg by digital weighing scale (Indo Surgicals, New Delhi, India). Height was measured without shoes to the nearest 0.1 cm by rigid stadiometer (Indo Surgicals, New Delhi, India), and BMI was calculated as weight (kg) divided by the square of height (m).
b. Cardiovascular assessment: All recordings were done using "Omron HEM 7130" automatic blood pressure monitor (a validated machine).[25] Systolic blood pressure (SBP), diastolic blood pressure (DBP), and HR were recorded immediately before and after the experimental trial. Pulse pressure (PP) was estimated as PP = SBP-DBP.
c. Respiratory gas analysis: Breath analysis data were averaged during the last 2 min of the experimental trial to estimate RER (RER = VCO_2/VO_2) by ADInstruments Exercise Physiology System, New Delhi, India, using software "power lab v8."

Statistical Analysis

Primary data entry and calculations were done using an Excel Database (Microsoft Office Excel 2016). Further, statistical analyses were performed using the IBM SPSS Statistics Software for Windows v25.0.0.1 (IBM Corp., Armonk, New York. Released 2016). In the descriptive analyses, means with standard deviations were reported. For comparative statistics, paired samples *t*-test was applied. The $P < 0.05$ was considered statistically significant.

RESULTS

All participants did AE on both TM and CE without any dropouts. Table 1 represents characteristics of the participants. Table 2 shows that there was no significant difference in the cardiovascular variables before CE and TM exercise. Hence, CE and TM groups were comparable at baseline. Among cardiovascular variables, only HR tended ($P = 0.063$) to increase after TM than CE exercise. Table 3 shows the comparison of respiratory gas analysis parameters after CE and TM exercise. VO_2 in L/min was significantly ($P = 0.049$) higher in TM than CE exercise.

DISCUSSION

This study was conducted to determine the RER and cardiovascular response to AE done on TM and CE by moderately active, healthy, and young males for 30 min at similar RPE of 13. The results of the present study showed that RER, SBP, DBP, and PP do not differ statistically in TM and CE AE. HR was non-significantly higher in TM than CE AE. VO_2 was significantly higher in TM than CE. It was estimated that participants were exercising at 70% of their HR_{max} (calculated by the formula proposed by Tanaka *et al*.)[26] during TM and 68% of their HR_{max} during CE AE.

Table 1: Characteristic of participants (*n*=16)

Parameters	Mean±SD
Age in years	21.3±1.4
Height in cm	167.1±3.2
Weight in kg	57.9±4.0
BMI in kg/m²	20.8±1.6

BMI: Body mass index, SD: Standard deviation

Table 2: Comparison of cardiovascular parameters before and after CE and TM exercise (***n***=16)

Parameters	Before TM	Before CE	*P*	After TM	After CE	*P*
SBP (mmHg)	119.7±4.6	119.8±4.3	0.718	145.3±8.4	146.8±6.6	0.224
DBP (mmHg)	76.7±4.4	76.8±4.5	0.751	73.6±5.1	74.6±3.5	0.131
HR (per min)	76.8±7.1	76.9±7.6	0.423	135.7±9.9	131.6±8.6	0.063
PP (mmHg)	43.1±2.6	43.0±2.2	0.791	71.7±7.3	72.3±6.4	0.549

Data expressed as mean±SD, *P*<0.05 is significant, paired t-test was applied to compare the means. CE: Cycle ergometer, TM: Treadmill, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, HR: Heart rate, PP: Pulse pressure, SD: Standard deviation

Table 3: Comparison of RER and VO_2 after CE and TM exercise (*n*=16)

Parameters	After TM	After CE	*P*
RER	0.89±0.05	0.91±0.06	0.148
VO_2 L/min	1.11±0.17	1.03±0.16	0.049

Data expressed as mean±SD, $P<0.05$ is significant, paired *t*-test was applied to compare the means. SD: Standard deviation, RER: Respiratory exchange ratio, CE: Cycle ergometer, TM: Treadmill

Bolgar *et a*l. (2010)[27] reported that RPE is a valid tool to match relative exercise intensity of TM and CE as the overall RPE does not vary significantly in both the modalities irrespective of training status. RPE has a strong and linear correlation with HR, VO_2, and blood lactate level during exercise but remains unaffected by exercise modality, physical activity level, age, and gender.[15,28] Thus, comparing responses to TM and CE on the basis of RPE is a valid and practical approach.

Based on earlier studies,[29-31] it has been postulated by various researchers[5-10] that TM utilizes greater active muscle mass than the CE. Exercise pressor reflex depends on the stimulation of mechanoreceptors and metaboreceptors.[32] Greater the muscle mass involved in the exercise higher would be the stimulation of mechanoreceptors; however, acidosis and lactate concentration occurs more in CE than TM[30,31] that might cause higher stimulation of metaboreceptors in CE as compared to TM. Cardiovascular response to exercise is multifactorial and may depend on the movement pattern, proportion of eccentric, concentric, and isometric contraction, feed-forward and feed-back mechanism of blood flow regulation, and familiarity with movement pattern involved in the exercise.[33]

It has been postulated that VO_{2max} is 7–10% higher in TM than CE[29,30] due to greater muscle mass involvement in TM, which could also explain the significantly higher VO_2 obtained in our study after TM than CE AE. Our results are in direct agreement with the results reported by Zeni *et al*. who reported that TM resulted in highest energy expenditure[34] and HR response[33,34] as compared to CE and four other indoor exercise machines at similar RPE in healthy and young adults.

Higher the RER greater the proportion of carbohydrates, while lower the RER greater the proportion of fat being oxidized for energy production.[16,17] In the present study RER in TM AE was 0.89 that corresponds to 64% carbohydrate and 36% fat contribution to total energy expenditure which was estimated to be 5.5 Kcal/min; while RER in CE was 0.91 that corresponds to 71% carbohydrate and 23% fat contribution to total energy expenditure of 5.1 Kcal/min.[17] The cause of greater fat oxidation in TM as compared to CE has not been elucidated till date, however several hypotheses had been proposed for the same. The most acceptable hypothesis for the present study could be the reduced activity of carnitine palmitoyltransferase I (a key enzyme required in fat metabolism[35]) due to the lower pH caused by greater anaerobic metabolism[31] during moderate intensity CE AE as compared to TM AE.

The results of our study are in disagreement with the results by King *et al*.[13] who reported that in moderately active women TM walk resulted in higher fat oxidation or lower RER, lower HR, and lower VO_2 than the CE exercise matched at RPE of 13. King *et al*. explained that in CE there might be the higher release of catecholamines that promote glycogenolysis, and hence, at similar RPE, CE resulted in lower fat oxidation and higher HR response than TM exercise. However, catecholamines are an inducer of lipolysis[36] not glycogenolysis. Moreover, catecholamine levels were reported higher after running than cycling for 2.5 h,[37] and hence, Achten *et al*.[8] and Capostagno and Bosch[10] did not supported the hypothesis that catecholamine could be a cause of different fat oxidation rates in TM and CE AE.

The total energy expenditure of an exercise program is essential for the improvement in the quality of life.[38] TM AE not only resulted in greater fat oxidation but also significantly higher energy expenditure as compared to CE AE. Thus, TM AE could be preferred over CE AE.

Limitations of the Study

There are several limitations in the study. VO_{2max} was not determined as the non-compliance of participants occurred toward maximal intensity exercise protocol. Mouth breathing through face mask caused discomfort to the participants, and hence, metabolic data were collected during the last 2 min of the exercise trial. Participants were moderately active males of similar age, BMI, and ethnicity, so data cannot be applied to the population that is more diverse. Estimation of blood glucose, lactate, and free fatty acids was not done which could have strengthened the results of our study. The participants were asked to maintain a 1-day food diary, but they were not monitored for the same. The effects of these limitations on our study data are unclear and require further studies.

CONCLUSION

Energy expenditure was significantly higher while HR tends to be higher after 30 min of continuous moderate intensity AE on TM than CE. RER was non-significantly lower after TM indicating greater fat oxidation during TM as compared to CE. Detailed studies regarding the same are warranted for the external validity of our results.

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REFERENCES

1. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: Surveillance progress, pitfalls and prospects. Lancet 2012;380:247-57.
2. Pedersen BK. The diseasome of physical inactivity–and the role of myokines in muscle–fat cross talk. J Physiol 2009;587:5559-68.
3. Donnelly JE, Honas JJ, Smith BK, Mayo MS, Gibson CA, Sullivan DK, *et al.* Aerobic exercise alone results in clinically significant weight loss for men and women: Midwest exercise trial 2. Obesity (Silver Spring) 2013;21:E219-28.
4. Polen ZK, Joshi S. Comparison of treadmill versus cycle ergometer training on functional exercise capacity in normal individuals. Int J Curr Res Rev 2014;6:61-5.
5. Lafortuna CL, Agosti F, Galli R, Busti C, Lazzer S, Sartorio A, *et al.* The energetic and cardiovascular response to treadmill walking and cycle ergometer exercise in obese women. Eur J Appl Physiol 2008;103:707-17.
6. Lafortuna CL, Lazzer S, Agosti F, Busti C, Galli R, Mazzilli G, *et al.* Metabolic responses to submaximal treadmill walking and cycle ergometer pedalling in obese adolescents. Scand J Med Sci Sports 2010;20:630-7.
7. Zakrzewski JK, Tolfrey K. Comparison of fat oxidation over a range of intensities during treadmill and cycling exercise in children. Eur J Appl Physiol 2012;112:163-71.
8. Achten J, Venables MC, Jeukendrup AE. Fat oxidation rates are higher during running compared with cycling over a wide range of intensities. Metabolism 2003;52:747-52.
9. Chenevière X, Malatesta D, Gojanovic B, Borrani F. Differences in whole-body fat oxidation kinetics between cycling and running. Eur J Appl Physiol 2010;109:1037-45.
10. Capostagno B, Bosch A. Higher fat oxidation in running than cycling at the same exercise intensities. Int J Sport Nutr Exerc Metab 2010;20:44-55.
11. Knechtle B, Müller G, Willmann F, Kotteck K, Eser P, Knecht H, *et al.* Fat oxidation in men and women endurance athletes in running and cycling. Int J Sports Med 2004;25:38-44.
12. Kisan R, Kisan SR, Anitha OR, Chandrakala SP. Treadmill and bicycle ergometer exercise: Cardiovascular response comparison. Glob J Med Res 2012;12:23-5.
13. King L, Sillers W, McCarthy K, Louis P, Astorino TA. Higher fat oxidation during treadmill walking versus cycle ergometry in active women at equal RPE: A pilot study. J Sports Med Phys Fitness 2016;56:1298-303.
14. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982;14:377-81.
15. Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M, *et al.* Associations between borg's rating of perceived exertion and physiological measures of exercise intensity. Eur J Appl Physiol 2013;113:147-55.
16. Lusk G. Animal calorimetry: Twenty-fourth paper. Analysis of the oxidation of mixtures of carbohydrate and fat. J Biol Chem 1924;59:41-2.
17. Katch VL, McArdle WD, Katch FI. Essentials of Exercise Physiology. 4th ed. China: Lippincott Williams & Wilkins; 2011. p. 219.
18. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39:175-91.
19. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157-63.
20. Health Department of UK. General Practice Physical Activity Questionnaire (GPPAQ). https://www.gov.uk/government/publications/generalpractice-physical-activity-questionnaire-gppaq. [Last cited on 2018 Jan 01]; [Last accessed on 2013 Apr 23].
21. Canadian Society for Exercise Physiology. PAR-Q Forms. Available from: http://www.csep.ca/view.asp?ccid=517. [Last cited on 2017 Jan 01].
22. Misra A, Nigam P, Hills AP, Chadha DS, Sharma V, Deepak KK, *et al.* Consensus physical activity guidelines for asian indians. Diabetes Technol Ther 2012;14:83-98.
23. Pescatello LS, Arena R, Riebe D, Thompson PD. ACSM's Guidelines for Exercise Testing and Prescription. 9th ed. China: Lippincott Williams & Wilkins; 2014. p. 165, 174.
24. Brown SP, Miller WC, Eason JM. Exercise physiology basis of human movement in health and disease. USA: Lippincott Williams & Wilkins; 2006. p. 115.
25. Takahashi H, Yoshika M, Yokoi T. Validation of three automatic devices for the self-measurement of blood pressure according to the European society of hypertension international protocol revision 2010: The Omron HEM-7130, HEM-7320F, and HEM-7500F. Blood Press Monit 2015;20:92-7.
26. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. J Am Coll Cardiol 2001;37:153-6.
27. Bolgar MR, Baker CE, Goss FL, Nagle E, Robertson RJ. Effect of exercise intensity on differentiated and undifferentiated ratings of perceived exertion during cycle and treadmill exercise in recreationally active and trained women. J Sports Sci Med 2010;9:557-63.
28. Lambrick DM, Faulkner JA, Rowlands AV, Eston RG. Prediction of maximal oxygen uptake from submaximal ratings of perceived exertion and heart rate during a continuous exercise test: The efficacy of RPE 13. Eur J Appl Physiol 2009;107:1-9.
29. Hermansen L, Saltin B. Oxygen uptake during maximal treadmill and bicycle exercise. J Appl Physiol 1969;26:31-7.
30. Koyal SN, Whipp BJ, Huntsman D, Bray GA, Wasserman K. Ventilatory responses to the metabolic acidosis of treadmill and cycle Ergometry. J Appl Physiol 1976;40:864-7.
31. Miles DS, Critz JB, Knowlton RG. Cardiovascular, metabolic, and ventilatory responses of women to equivalent cycle ergometer and treadmill exercise. Med Sci Sports Exerc 1980;12:14-9.
32. Murphy MN, Mizuno M, Mitchell JH, Smith SA. Cardiovascular regulation by skeletal muscle reflexes in health and disease. Am J Physiol Heart Circ Physiol 2011;301:H1191-204.
33. Zeni AI, Hoffman MD, Clifford PS. Relationships among heart rate, lactate concentration, and perceived effort for different types of rhythmic exercise in women. Arch Phys Med Rehabil 1996;77:237-41.
34. Zeni AI, Hoffman MD, Clifford PS. Energy expenditure with

indoor exercise machines. JAMA 1996;275:1424-7.
35. Starritt EC, Howlett RA, Heigenhauser GJ, Spriet LL. Sensitivity of CPT I to malonyl-coA in trained and untrained human skeletal muscle. Am J Physiol Endocrinol Metab 2000;278:E462-8.
36. Polak J, Bajzova M, Stich V. Effect of exercise on lipolysis in adipose tissue. Future Lipidol 2008;3:557-72.
37. Nieman DC, Nehlsen-Cannarella SL, Fagoaga OR, Henson DA, Utter A, Davis JM, *et al*. Effects of mode and carbohydrate on the granulocyte and monocyte response to intensive, prolonged exercise. J Appl Physiol (1985) 1998;84:1252-9.
38. Cornelissen VA, Buys R, Pattyn N. High intensity interval training in coronary artery disease patients, is it worth the effort? Eur J Prev Cardiol 2017;24:1692-5.

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