REVIEW ARTICLE

Impact of Eccentric Cycling on Physical Performance and Physiological Responses in Clinical Population: A scoping review

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ABSTRACT

Eccentric (ECC) cycling has been implemented to enhance functional performance in the clinical population due to its low cardiopulmonary demand. Nevertheless, there is a scarcity of studies conducted in clinical populations with diverse deficits. Therefore, we systematically searched four databases (Scopus, ScienceDirect, Web of Science, and Google Scholar) for published studies evaluating the effects of ECC cycling exercise on physical performance and physiological response in these populations. This review includes 7 studies involving 138 patients based on inclusion and exclusion criteria. None of the studies reported any serious injuries. Most studies reported that ECC cycling is feasible and safe for patients, and it has positive effects such as reduced cardiorespiratory workload, perceptual rating, and increased physical performance. Current evidences suggest ECC cycling has a promising impact on clinical populations, primarily in cardiorespiratory disorders. Further research is recommended to explore ECC cycling in a broader range of clinical conditions.

Malaysian Journal of Medicine and Health Sciences (2025) 21(SUPP10):156-160. doi:10.47836/mjmhs.21.s10.30

Keywords: Clinical population; eccentric cycling; eccentric exercise; rehabilitation; physical performance

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INTRODUCTION

Eccentric (ECC) cycling has gained interest as a rehabilitation training apparatus due to its low cardiometabolic demand compared to concentric (CONC) cycling (traditional cycling) (1). It is a unique form of exercise that incorporates the contraction of muscle while lengthening during the cycling motion, known as ECC muscle contractions (2,3). The motorized pedals in ECC cycling are propelled in a reverse direction, requiring the rider to counteract this backward movement, resulting in ECC contraction, particularly the knee extensor (3,4). This ECC cycling exercise is beneficial in clinical settings as it allows patients to perform a higher workload with less cardiorespiratory strain than CONC cycling under equivalent physiological demands, making it an ideal intervention for patients with ventilatory constraints and locomotor muscle dysfunction (3,5,6).

Prior research reported that ECC cycling provides several physical and physiological benefits for individuals with clinical conditions, including improvement in muscle strength, perceived exertion, and functional mobility, particularly in chronic obstructive pulmonary disease (COPD) (2,7). Additionally, this equipment is linked to favourable hemodynamic responses such as efficient oxygen uptake and enhanced blood pressure regulation (2,7). Despite these promising benefits of ECC cycling, studies are scarce in clinical populations with diverse deficits. Hence, this scoping review aims to provide an overview of the existing literature regarding the potential benefits of ECC cycling on physical performance and physiological response in clinical populations.

MATERIAL AND METHODS

Study Design

This scoping review was carried out following a standardized methodological framework (8). The identification and screening procedure for article selection adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (9).

Search Strategy

The search used four electronic databases (Science Direct, Web of Science, Scopus, and Google Scholar) to identify studies describing the effects of ECC cycling compared to CONC cycling on clinical populations. A comprehensive search of academic journals published on this topic from 2015 until 10th October 2024 was performed. The search included the following keywords and Boolean operators: (“Effects” OR “Impacts”) AND (“Eccentric cycling” OR “Eccentric ergometer” OR “Eccentric pedaling”) AND (“Clinical populations” OR “Patients”) AND (Rehabilitation).

Eligibility Criteria

Only studies published in English were considered. The articles selected for review met the following inclusion criteria: (1) studies that implement ECC cycling as an intervention in clinical populations and (2) studies that investigated the effect of ECC cycling on physical performance AND/OR physiological responses. Studies that included participants other than the clinical population (e.g. athletes, healthy individuals), review papers, study protocols, pilot studies, case studies, and reports were excluded from this review.

Study Selection

All studies were imported into Mendeley. The reviewers (R.A.A.R and S.S.) screened titles and abstracts for eligibility. Selected studies underwent full-text screening (A.M.C.M and H.A.Y) with discrepancies resolved by consensus.

Data Extraction

Table I presents a summary of the extracted data from selected studies. The Data were organized to summarize the main findings of the impact of ECC cycling training on physical performance and physiological responses in clinical populations.

RESULT

Figure 1 presents a PRISMA-ScR flow diagram illustrating the phases of article screening and selection. A total of 629 articles were identified, with 30 duplicates removed and 589 articles excluded based on title and abstract screening, which resulted in 10 potentially relevant articles for the present study. Further full-text screening resulted in the elimination of 3 additional papers, yielding a total of 7 studies eligible for data extraction (2,3,5,7,10–12). The 3 studies were excluded as one is a study protocol publication, and another is a report and review paper.

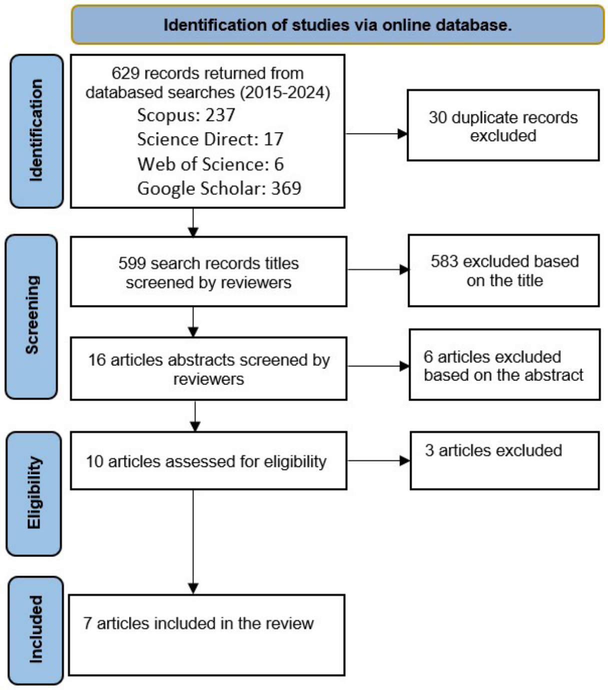

Figure 1: PRISMA-ScR study flow diagram

Six of the studies involved a clinical population with COPD from moderate to severe, while only one study included patients with pulmonary vascular diseases (PVD). Three of the seven studies were randomized controlled trials (3,5,11). In total, 138 participants were divided into ECC cycling, CONC cycling, or both types of cycling, with sample sizes ranging from n=10 to n=33. The average age of the participants was between 50 ± 15 years to 69.6 ± 10.1 years. Regarding sex distribution, most studies encompassed both genders, except for two studies (5,11) that exclusively involved male participants.

DISCUSSION

Effects of ECC Cycling on the Investigated Outcome Measures in Clinical Populations

Physiological Responses

The physiological response (Table I) indicated that ECC cycling generally elicits lower cardiorespiratory demands than CONC cycling across these studies. Three studies (2,7,12) reported decreased oxygen uptake (VO_2), minute ventilation (VE), and heart rate in ECC relative to CONC cycling. Study findings by Inostroza et

Table I: Impact of ECC cycling on physical performance and physiological responses

Study, year	Outcome measure		Main finding	Adverse event
Müller et al.(12), 2024	-VO_2 - V_E - sPAP	-TAPSE/sPAP -Borg CR10 -ABG (PaCO2, PaO2)	- VO_2, V_E, sPAP, PaCO2, and Borg CR10 perceived dyspnea ↓ in the ECC than in CONC. -TAPSE/sPAP and arterial pH ↑ in the ECC than in the CONC.	- No
Bourbeau et al.(11), 2020	- V_E -Dyspnea RPE - stair climbing - 6MWT - Isometric QPT - Isokinetic QPT	- Isokinetic QPP - Concentric PPO - Endurance time in CONC cycling test at 75% PPO - Leg fatigue RPE	- Dyspnea and leg fatigue RPE ↓ in ECC than in CONC. - Isometric QPT ↑ in the ECC than in CONC. - Isokinetic QPT, QPP, and 6WT ↑ only in ECC. - Concentric PPO and exercise endurance time ↑ in both groups.	-Two patients in the ECC group present with knee pain due to a pre-existing osteoarticular problem.
Ward et al.(7), 2020	- VO_2 - V_E - HR - SBP	- Borg scale - capillary lactate concentration - Muscle metabolites	- VO2, V_E, HR, SBP, Borg scale for dyspnea and leg fatigue, and capillary lactate ↓ during ECC and CONC in both COPD and healthy control groups.	- Not reported
Inostroza et al. (3), 2021	- Workload - HR - Dyspnea RPE - SPO_2 - LLFFM - LLFM - QoL	- MVC strength of knee extensors - RFD - 6MWT - TUG - SAWT - SDWT	- Workload, SPO2, and LLFFM were greater in ECC than in CONC. - HR and dyspnea were ↓ in ECC than in CONC. -RFD ↑, 6MWT ↑, and TUG ↓ only in ECC. - SAWT and SDWT ↓ in both groups. - QoL ↑ in both groups	- Not reported
Nahmias et al.(10), 2021	- V_T - f_B - IC - VO_2	-Ventilatory efficiency - EMG activity	-V_T and IC ↓ in ECC than in CONC - f_B ↑ in ECC than in CONC - Ventilatory efficiency was ↓in ECC than in CONC. - EMG of the biceps brachialis ↑during ECC than CONC.	- Not reported
Nickel et al. (2), 2020	- VO_2 - VE -HR - fR - SPO_2	- SBP - DBP - RPE - Dyspnea -Power output	- VO_2, V_E, HR, SBP, f_R, SBP, RPE, and dyspnea were ↓ during moderate ECC than moderate CONC - - Average power output ↑ during high-intensity ECC	- Not reported
MacMillan et al. (5), 2017	- Dyspnea RPE - HR - Muscle Biopsy - Mitochondrial biogenesis	- Isometric QPT - Total isokinetic work - thigh lean mass - Leg fatigue RPE	- HR and RPE score for both dyspnea and leg fatigue ↓ during ECC than during CONC - Isometric QPT, total isokinetic work, and thigh lean mass ↑ in ECC only.	-One patient experienced an acute exacerbation and two patients experienced knee pain in the EET group

ABG, arterial blood gas; DBP, diastolic blood pressure; fB, breathing frequency; fR, respiratory frequency; HR, heart rate; IC, inspiratory capacity; LLFM, lower limb fat mass ; LLFFM, lower limb fat-free mass ; PPO, peak power output; QoL, quality of life; QPP, quadriceps peak power; QPT, quadriceps peak torque; RFD, rate of force development; SAWT, stairs ascending walking time; SBP, systolic blood pressure; SDWT, stairs descending walking time; sPAP, systolic pulmonary arterial pressure ; SPO2, oxygen saturation ; TAPSE, tricuspid annular plane systolic excursion; VE, minute ventilation; VO2, oxygen uptake; VT, tidal volume;↑, increase;↓ decrease.

al. (3) observed a lower HR and higher oxygen saturation (SPO2) during ECC, reinforcing the notion that ECC imposes a reduced cardiorespiratory load. Additionally, most studies showed that ECC cycling is associated with lower Borg scale or RPE scores for dyspnea and leg fatigue (2,3,5,7,11,12).

These data demonstrated that ECC cycling exerts less physical and respiratory load which may be attributed to decreased muscle fiber activation during ECC for the same force output as CONC (13). In contrast, Nahmias et al. (10) showed that ventilatory efficiency was poorer in ECC compared to CONC in severe COPD patients, with an elevated breathing frequency observed in ECC, a result not prominently noted in another research. ECC cycling regularly exhibits reduced blood pressure compared to CONC cycling. This assertion is confirmed by two studies (2,7) demonstrating a reduction in systolic blood pressure during ECC cycling in COPD patients. This finding is associated with the reduced metabolic demand of eccentric cycling. Furthermore, the study by Mьller et al. (12) reported systolic pulmonary arterial pressure (sPAP) was reduced, while tricuspid annular plane systolic excursion/sPAP (TAPSE/sPAP), indicative of right ventricular-arterial coupling, was elevated in PVD patients during ECC cycling. A lower sPAP correlates with reduced right ventricular load and a reduced risk of decompensation during exercise (14), as evidenced by the higher TAPSE/sPAP during ECC, indicating an improvement in right ventricular contractile response (15).

Physical Performance

ECC cycling demonstrated a beneficial effect on various aspects of physical performance, including muscle strength, exercise capacity, and functional performance in clinical populations. Three studies (3,5,11) proved that ECC cycling significantly increased muscle strength, particularly in the quadriceps, encompassing isometric work, isokinetic work, maximal voluntary contraction (MVC), and thigh lean mass. Furthermore, the CONC and ECC groups improved peak power output (PPO) and endurance time (11). Only the ECC cycling group demonstrated improvement in exercise capacity as evidenced by increased distance in the 6-minute walk test (6MWT) (3,11). A study showed that ECC cycling resulted in enhanced functional performance, indicated by reduced completion times for the Timed Up and Go (TUG) test, stairs ascending walking time (SAWT), and stairs descending walking time (SDWT) (3). Nevertheless, certain studies (7,10,12) did not evaluate or report these outcomes, concentrating on cardiorespiratory and metabolic responses. This indicates a divergence in research emphasis, with some studies focussing on physical performance and others on the cardiopulmonary effects of ECC cycling.

Adverse Events Related to ECC Cycling

The significant adverse events associated with ECC cycling were minimal with two studies (5,11) reported that participants experienced knee pain during ECC cycling exercise due to pre-existing osteoarticular issues and one participant experienced an acute exacerbation during ECC cycling (5). However, all these participants completed the course during the training. This suggests that ECC cycling is generally safe and well-tolerated.

CONCLUSION

ECC cycling is feasible and well-tolerated in COPD and PVD patients. The intervention consistently led to reduced cardiorespiratory strain, and lower perceived exertion, though it may challenge ventilation in severe COPD cases. It also improved muscle strength, functional performance, and LLFFM compared to conventional cycling, particularly in patients with COPD. ECC cycling protocols were generally well-tolerated; however, some participants reported knee pain, with no significant adverse events noted. Consequently, caution is advised for individuals with pre-existing joint conditions. Overall, ECC cycling exhibits a promising impact on the clinical population, albeit limited to cardiorespiratory disorders. Further research should explore ECC cycling as an intervention in different clinical populations.

ACKNOWLEDGEMENTS

The authors express gratitude to Universiti Sains Malaysia and UiTM Cawangan Pulau Pinang for the support.

REFERENCES

1. Clos P, Laroche D, Stapley PJ, Lepers R. Neuromuscular and perceptual responses to sub-maximal eccentric cycling. Front Physiol. 2019;10(354):1–10. doi: 10.3389/fphys.2019.00354.
2. Nickel R, Troncoso F, Flores O, Gonzalez-Bartholin R, Mackay K, Diaz O, et al. Physiological response to eccentric and concentric cycling in patients with chronic obstructive pulmonary disease. Appl Physiol Nutr Metab. 2020;45(11):1232–7. doi: 10.1139/apnm-2020-0149.
3. Inostroza M, Valdйs O, Tapia G, Nъcez O, Kompen MJ, Nosaka K, et al. Effects of eccentric vs concentric cycling training on patients with moderate COPD. Eur J Appl Physiol. 2022;122(2):489–502. doi: 10.1007/s00421-021-04850-x.
4. Elmer SJ, McDaniel J, Martin JC. Alterations in neuromuscular function and perceptual responses following acute eccentric cycling exercise. Eur J Appl Physiol. 2010;110(6):1225–33. doi: 10.1007/s00421-010-1619-z.

5. MacMillan NJ, Kapchinsky S, Konokhova Y, Gouspillou G, Sena R de S, Jagoe RT, et al. Eccentric ergometer training promotes locomotor muscle strength but not mitochondrial adaptation in patients with severe chronic obstructive pulmonary disease. Front Physiol. 2017;8(114):1–14. doi: 10.3389/fphys.2017.00114.
6. Barreto R V, Lima LCR, Borszcz FK, de Lucas SD, Denadai BS. Acute physiological responses to eccentric cycling: a systematic review and meta-analysis. J Sports Med Phys Fitness. 2023;63(10):1051–68. doi: 10.23736/S0022-4707.23.14971-1.
7. Ward TJC, Lindley MR, Ferguson RA, Constantin D, Singh SJ, Bolton CE, et al. Submaximal eccentric cycling in people with COPD: Acute whole-body Cardiopulmonary and muscle metabolic responses. Chest. 2021;159(2):564–74. doi: 10.1016/j.chest.2020.08.2082.
8. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. Int J Social Research Methodology. 2005;8(1):19–32. doi: 10.1080/1364557032000119616.
9. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. Ann Intern Med. 2018;169(7):467–73. doi: 10.7326/M18-0850.
10. Nahmias O, Ritter O, Sagawa Y, Roux P, Degano B, Soumagne T. Ventilatory adaptation during eccentric cycling in patients with severe COPD: Potential implications for exercise training. Respir Physiol Neurobiol. 2021;292(103706):1–7. doi: 10.1016/j.resp.2021.103706.
11. Bourbeau J, De Sousa Sena R, Taivassalo T, Richard R, Jensen D, Baril J, et al. Eccentric versus conventional cycle training to improve muscle strength in advanced COPD: A randomized clinical trial. Respir Physiol Neurobiol. 2020;276(103414):1–9. doi: 10.1016/j.resp.2020.103414.
12. Müller J, Schneider SR, Titz A, Thalmann C, Schwarz EI, Bauer C, et al. Effect of eccentric cycling on oxygen uptake and hemodynamics in patients with pulmonary vascular disease. CHEST Pulmonary. 2024;2(2):1–12. doi: 10.1016/j.chpulm.2024.100054
13. Maeo S, Shan X, Otsuka S, Kanehisa H, Kawakami Y. Neuromuscular adaptations to work-matched maximal eccentric versus concentric training. Med Sci Sports Exerc. 2018 Aug 1;50(8):1629–40. doi: 10.1249/MSS.0000000000001611
14. Humbert M, Kovacs G, Hoeper MM, Badagliacca R, Berger RMF, Brida M, et al. 2022 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension.Eur Heart J. 2022; 43(38): 3618–731. doi: 10.1093/eurheartj/ehac237
15. Tello K, Wan J, Dalmer A, Vanderpool R, Ghofrani HA, Naeije R, et al. Validation of the Tricuspid Annular Plane Systolic Excursion/Systolic Pulmonary Artery Pressure Ratio for the Assessment of Right Ventricular-Arterial Coupling in Severe Pulmonary Hypertension. Circ Cardiovasc Imaging. 2019;12(9): 1–11. doi: 10.1161/CIRCIMAGING.119.009047