Journal of Taibah University Medical Sciences (2024) 19(1), 136–150

Taibah University

Journal of Taibah University Medical Sciences

www.sciencedirect.com

Review Article

Stair-climbing interventions on cardio-metabolic outcomes in adults: A scoping review

Anang M. Ghosal, BSc and Baskaran Chandrasekaran, MPT *

Department of Exercise and Sport Sciences, Manipal College of Health Professions, Manipal Academy of Higher Education, Manipal, Karnataka, India

Received 5 May 2023; revised 30 July 2023; accepted 13 October 2023; Available online 1 November 2023

الملخص

أهداف البحث: يرتبط الخمول البدني بارتفاع مخاطر الإصابة بالأمراض المزمنة؛ ومع ذلك، فإن جزءا صغيرا فقط من سكان العالم يستوفي التوصيات الخاصة بالنشاط البدني. صعود السلالم هو شكل بسيط وسهل من النشاط البدني الذي ثبت أنه يحسن نتائج القلب والأوعية الدموية لدى البالغين. يستكشف استعراض النطاق الحالي الآثار الفسيولوجية والعلاجية لتدخلات صعود السلالم على عوامل خطر الإصابة بأمراض القلب والأوعية الدموية لدى البالغين.

طرق البحث: اتبعت مراجعة النطاق هذه إرشادات الإبلاغ الخاصة بإطار عمل آركسي و أومالي، الذي يجمع الأدلة على مراحل. تم تأطير سؤال البحث على أنه "ما هي آثار صعود السلالم على نتائج القلب والأوعية الدموية لدى البالغين؟". تم تحديد المقالات المؤهلة من خلال بحث مكثف في أربع قواعد بيانات إلكترونية، وتم مراجعة وتنظيم بيانات من 24 دراسة بحثية.

النتائج: يحسن صعود السلالم القدرة الهوائية (8-33 مل كجم / دقيقة) والمؤشرات الحيوية في الدم بنسبة ≈ 9-15٪. كما أظهرت المراجعة أن ما لا يقل عن 4 - 8 أسابيع من النشاط ضرورية لتغيير مخاطر القلب والأوعية الدموية. يمكن أن يؤدي صعود السلالم المنتظم إلى تحسين مؤشرات مخاطر القلب والتمثيل الغذائي، بما في ذلك تكوين الجسم وضغط الدم ومستويات الكوليسترول وحساسية الأنسولين. لا يزال البحث المتعلق بالتغيرات الالتهابية والعضلية الهيكلية مع نوبات صعود السلالم في مهده.

الاستنتاجات: تدخلات صعود السلالم هي شكل من أشكال النشاط البدني بدون تكلفة وسهلة لتحسين مخاطر الإصابة بأمراض القلب والأوعية الدموية لدى البالغين.

الكلمات المفتاحية: البالغين؛ نتائج القلب والأوعية الدموية؛ النشاط البدني؛ صعود السلالم؛ مراجعة النطاق؛ الخمول البدني

Abstract

Objective: Physical inactivity is linked with high chronic disease risk; however, only a fraction of the global population meets the recommendations for physical activity. Stair-climbing is a simple and accessible form of physical activity that has been shown to improve cardio-metabolic outcomes in adults. The present scoping review explores the physiological and therapeutic effects of stair-climbing interventions on adult cardio-metabolic disease risk factors.

Methods: This scoping review followed the reporting guidelines of the Arksey & O'Malley framework, which collates evidence in stages. The research question was framed as "What are the effects of stair climbing on cardio-metabolic outcomes in adults?". Eligible articles were identified through an extensive search of four electronic databases, and data from 24 research studies were charted and organized.

Results: Stair climbing improves aerobic capacity (8–33 ml kg/min) and serum biomarkers by ≈9–15 %. A minimum of 4–8 weeks are necessary to alter cardiometabolic risk. Regular stair climbing can improve cardio-metabolic risk indicators, including body composition, blood pressure, cholesterol levels, and insulin sensitivity. The research regarding inflammatory and musculoskeletal changes with stair climbing bouts is still in its infancy.

Conclusion: Stair climbing interventions are a no-cost and feasible form of physical activity for improving cardiometabolic disease risk in adults.

Keywords: Adults; Cardio-metabolic outcomes; Physical activity; Scoping review; Sedentary; Stair-climbing

* Corresponding address: Department of Exercise and Sport Sciences, Manipal College of Health Professions, Manipal Academy of Higher Education, Manipal, Karnataka, India.
E-mail: baskaran.c@manipal.edu (B. Chandrasekaran)

Peer review under responsibility of Taibah University.

ELSEVIER Production and hosting by Elsevier

 https://doi.org/10.1016/j.jtumed.2023.10.003

Introduction

Cardiovascular diseases (CVDs) are the leading cause of death globally, with an estimated ≈ 19 million people dying from CVD, amounting to an 18.7 % mortality increase in 2020.[1] Though CVD is continued to be a threat to the global economy and health, more than three-quarters of deaths due to CVDs occurred in low- and middle-income countries.[2] Obesity, diabetes, hypertension, hyperlipidemia are speculated to be the precursors for both central and peripheral vascular diseases, eventually leading to coronary artery diseases and other CVD. Further cardiorespiratory fitness is a determinant of CVD risk and mortality.[3] Despite medical and surgical advances, a considerable segment of the global population, particularly in low-middle income countries, lacks access to medical and surgical management. Hence the above burden has forced public health experts to design cost-effective, feasible interventions for ameliorating cardiometabolic disease risk factors, especially but not limited to high blood glucose, lipid levels, inflammation and body mass index.

Epidemiological evidence shows a strong link between physical inactivity (not able to reach the global recommendations of more than 150 min of weekly moderate to vigorous activity) and cardiometabolic risk factors.[4] Optimum dose of physical activity is found to be beneficial in improving cardiometabolic risk. However, only a fraction of the global population meets the weekly recommendation for physical activity.[5] Feasibility, cost and embedding physical activity modality which integrates into everybody lives and ready availability are claimed to be the challenges in administering and advocating physical activity.

Stair climbing can be a no-cost, practical, feasible form of physical activity for improving cardiovascular health and reducing the risk of cardiometabolic diseases.[6–8] Accumulating evidence has shown that regular stair climbing can improve cardiometabolic risk indicators, including blood pressure, cholesterol levels, and insulin sensitivity.[8–11] Incorporating stair climbing into daily routines can result in significant improvements in cardiorespiratory fitness and a reduction in waist circumference.[12] Emerging evidence indicate that brief stair climbing sessions (for instance, four flights of stairs per day) can yield comparable benefits in preventing cardiometabolic risks, akin to those observed in more extended periods of regular physical activity trials.[13,14] However, the optimal dose, safety concerns associated with stair climbing have been overlooked.

The emerging scientific knowledge regarding the effectiveness of stair-climbing interventions remains unconsolidated. The consolidated findings may equip public health experts, behavioral scientists and policy makers in adapting feasible movement interventions and townplanning strategies for effective physical activity promotion. The present review may provide a breadth of knowledge about the effectiveness of stair climb interventions as stair climbing can be a practical, convenient form of exercise and also an effective way to accumulate physical activity throughout the day, especially for individuals who may not have the time or resources to engage in structured exercise.

Materials and Methods

The scoping review serves two purposes: (1) rapid assessment of emerging evidence and (2) identifying research gaps and paying the way for future systematic reviews. The present review followed the reporting guidelines of Arksey & O'Malley framework, which collates the evidence in stages: (1) Identifying the research question; (2) Identifying relevant studies, (3) Study selection, (4) Charting the data, (5) Collating, summarizing, and reporting the results.

Identification of research question

The review's primary aim is to explore stair climbing's physiological effects on the cardiometabolic disease risk factors in adults. To serve the above purpose, the following question was framed 'What are the effects of stair climbing on cardio-metabolic outcomes in adults?'. We framed the study question based on the population, intervention or exposure, comparison and outcomes (PI(E)CO) format (Table 1). The studies to be included should have involved a target population of adults between the age of 18–65 years. It should have administered stair-climbing interventions in the lab or natural setting. The study included should have assessed any one of the following cardiometabolic risk outcomes, including but not limited to serum glucose, insulin, inflammatory markers, anthropometry – body mass, circumference, aerobic capacity, vascular compliance, heart rate recovery, heart rate variability and cardiac contractility functions. Table 1 shows the PICO format administered in the review for eligibility of the potential studies to be included.

Identification of relevant studies

A systematic search was performed on four databases (Embase, Cumulative Index to Nursing and Allied Health Literature, Web of Science and Scopus) to find potential studies for this review. The keyword search string was as follows: "stair-climbing", "stair", "stair use", "cardiovascular disease", "ischemic heart disease", "artery disease", "cardiometabolic risk", "body mass", "obes*", "fat", "glucose", "lipid", "lipoprotein", "fasting glucose", "insulin", "cholesterol", "triglyceride", "inflammatory", "nitric oxide", "maximum oxygen uptake", "aerobic metabolism", "aerobic capacity", "functional status", "diabetes", "cancer", "adult", "male", "female" appropriately combined by Boolean operators "AND" "OR". The first search was conducted on 24th January 2023. The final search was updated on 14th April 2023.

Table 1: Population, Intervention (exposure), Comparison and Outcomes (PI(E)CO) framework.

PICO	Eligibility criteria
Population	Adults, aged 18–65 years
Intervention/Exposure	Stair climbing, stair, stair use, stair climbing intervention
Comparison	Any physical intervention other than stair climbing or no intervention
Outcome	Cardiovascular diseases (ischemic heart disease, artery disease), cardiometabolic risk, BMI, blood biomarkers (glucose, lipid, lipoprotein, fasting glucose, insulin, cholesterol, triglyceride, nitric oxide), inflammation, ventilation (maximum oxygen uptake, aerobic capacity and metabolism), functional status, diseases (diabetes and cancer).
Exclusion criteria	
Population	Children
Interventions	Lifestyle interventions other than stair climbing, studies administer interventions to promote stair climbing alone
Outcome	Outcomes other than cardiometabolic risk
Language	Other than English
Publication	Abstracts and conference proceedings without full text

Study selection

The citations retrieved from the databases were uploaded to Endnote online, and duplicates were removed. After duplicate removal, the citations were screened at the title and abstract level based on the priori set eligibility criteria (Table 1). After the abstract screening, potential studies to be included were downloaded as full text and screened by two independent researchers (AM, BC). The reason for exclusion also was documented, and any disagreements were resolved by consensus.

Charting of obtained data

The data obtained from the citations were organized in a tabular form with the following components: author, year, country of origin, study design, population of study, interventions, outcomes and key findings. Table 2 illustrates the study characteristics of the included studies. Gender, number, and baseline characteristics described the population, while interventions were explained in terms of the frequency and duration of the stair-climbing interventions. The outcomes were explained based on method and frequency of measurement. The key findings were explained in terms of mean change in the measures and authors' point of view in the inferences.

Results

Characteristics of included studies

Of the four databases searched with the above search criteria, 1844 citations were deemed eligible for screening after the removal of duplicates. Most of the studies were irrelevant (N = 1651, 90 %), and few citations were excluded based on the criteria (N = 169, 9 %). Only a few studies were included (N = 24, 1.3 %). Figure 1 shows the studies screened and included in the scoping review.

Nature of the studies

Most of the 24 studies included are interventional studies (N = 21, 88 %). In comparison, two studies are observational, and one is narrative synthesis.[15] All the included studies originate from high-income countries (Japan - 5, United Kingdom - 2, Canada - 2, united states - 2, Cyprus - 2 followed by Taiwan, China, Denmark, South Korea and Malaysia, each contributing one). No published research has explored the effects in lower-income countries. Almost half of the studies (N = 11, 45 %) have been administered in the past four years (2019–2022). Table 2 demonstrates the studies' characteristics and critical findings consolidated for the scoping review.

Population

The total number of participants in the included studies is 1792. Most of the studies have been administered to healthy, while few explored the effects on the clinical population.[30–32] Few studies have looked explicitly at the favourable effects of stair climbing in office workers,[7,11,16,25,27] obese,[18,19,23] hypertension,[34] type 2 diabetes mellitus (T2DM),[33] elderly[22,29] and coronary artery diseases.[14] Diet and sleep were standardized in a few studies.[31]

Interventions

Most of the studies administered stair climbing intervention as a stand-alone intervention, while only a few administered it as an adjunct to exercise training.[29] The climb involves 140–300 steps per day with a vertical displacement of ≈17–23 m.[11,17,25] Stair climb is identified as moderate intensity (≈13 of RPE scale 6–20) on the self-paced climb. Studies have administered stair climbing interventions using both self and externally paced stair climbing velocity using both low cadence (60–75 steps/min) and high cadence rate (80–110 steps/min).[20,25] Randomization of interventions was seldom mentioned.[31] Majority studies explored the effects of stair climbing in the long term (> four weeks) while few studies administered in the short term (<1 day).[18,20,31]

Outcome

Several studies have focussed on examining serological markers (serum TG, TC, LDL, VLD, HDL)[8,11,17,20,25,28,31] and cardiorespiratory fitness as outcomes.[7,28] Almost all the studies have administered venous samples and assessed through immunoassays.[20,25] Body composition measures such as body mass index was routinely administered while reliable sources of fat percentages such as underwater

Table 2: Characteristics of the included studies.

Author year	Country	Design	Objective	Population	Intervention	Outcomes	Key findings
Andersen, 2013[16]	Denmark	Randomised controlled trial	To explore the effects of email prompts on stair climbing on CVD risk	160 office workers (125 F, aged 42 yrs, 90 % of work hours in sitting)	• randomly assigned (2:1 ratio) for 10 weeks (1) Intervention group: received email prompt-based stair climbing reminders for 10 min every day for 8 weeks (2) control group: pursued usual work	• Aerobic fitness: Increment cycle protocol • BP, BMI • Heart rate monitor at the main stair • Feasibility	• CRF ↑ 1.45 ml/min/kg at 10-week • SBP, DBP ↓ 4.81 mm Hg in email group • No significant changes in weight • Low cost email-based encouragements to do daily stair- at work may improves CVD risk among adults in sedentary occupations.
Azmi, 2022[11]	United Kingdom	Quasi experimental study	To investigate the stair climbing effects on glucose and lipid profiles	• 16 sedentary office workers, (11M, 5F) • Sedentary able to climb regularly	• Four-floors staircase continuously for 8 times a day spread across workdays for 8-week period for 2 min • Every hour prompt from computer • Pedometer measured steps and log-based stair climb • Control group: participants with the buildings less than 4 floors of university	• Venous samples • Fasting and 2hrs post prandial glucose, LDL, VLDL, HDL, triglycerides and total cholesterol • Enzymatic calorimetric assays	• Physiological improvements in LDL-C, TC, TC/HDL-C ratio, non-HDL-C and fasting blood glucose in the experimental group while no change in control group. • Mean change TG (-0.06 mmol/L), TC (−0.6 mmol/L), HDL-C (+0.16 mmol/L), LDL-C (no change), TC/HDL (−0.4) and FG (−0.16 mmol/L) • Behavioral response: no change in the floors climbed (linear, quadratic trends) • ↓in total step counts over the weeks of the study
Boreham, 2005[17]	Ireland	Non-randomised controlled trial	To investigate the effects of stair climbing on VO2max, blood lipids, and homocysteine levels among sedentary and healthy young women	• 18 sedentary women in university • No self reported chronic diseases limiting stair climbing	randomly assigned to 8 weeks (1) Intervention group: progressive stair climb. 2 bouts of climb every day, 5 days, increasing one climb every two week (2) control group	• VO2 max: incremental cycle test and metabolic cart • Blood lipids and homocysteine: venous samples (TC, TG, HDL, LDL)	• No significant changes in BMI, TC, HDL-C, TC/HDL-C ratio, TG, or homocysteine. • Compared to controls, the stair climbing group showed a significant ↑in VO2max (+3.5 ml/kg/min) and a ↓ in LDL-C (-0.34 mmoL/l).
Cabral-Santos, 2021[18]	Netherlands	Randomized controlled study	to determine whether breaking up prolonged sitting with stair climbing bouts with or without high carb diet alter acute inflammatory response.	40 [10 lean males, 10 overweight/obese (OW) males; 10 lean females. 10 OW females]	Four interventions: control group with 9 h sitting with (1) low carbohydrate or (2) high carbohydrate snack; and stair climbing intervention (15−30 s × 8) with (3) low carbohydrate and (4) high carbohydrate snacks	• At baseline, 3rd and 6th hour assessed • Immune: IL-6, TNF-α and Salivary Immunoglobulin A (SIgA)	• TNF-α levels remained same in both groups • At 540 min mark, Interleukin-6 (IL-6) reduces more in OW with HC snack group • Salivary Immunoglobulin A was always higher in lean and active group but OW adults had elevate levels on both conditions

(*continued on next page*)

Table 2 (*continued*)

Author year	Country	Design	Objective	Population	Intervention	Outcomes	Key findings
							• Stair-climbing post sedentary behaviour reduces acute IL-6 levels in plasma for •When stair-climbing is accompanied by changes in nutrition SIgA level was increased in OW population
Chen, 2017[19]	Taiwan	Quasi randomised experimental study	To compare effects on BMD, lipid profile, insulin sensitivity and physical fitness between DSE and ASE individuals.	• 30 obese • sedentary women (60−82 yr) • free from any noncommunicable diseases	• Three interventions: (1) descending stairs (DSE); (2) ascending stairs (ASE); (3) control groups • Twice per weeks, 12 weeks • Stairs of a 10-story building	• upper thigh circumference, muscle soreness, balance and the right calcaneus BMD • functional fitness tests for senior adults consisting of 30-s chair stand, 2-min step, 8-ft up and go, 6-min walk and 6-m tandem walk • Lipid profile, HOMA-IR, HbA1C • MVC of extensors	• HR, BP (−8.6 %) lower in DSE than ASE • No significant changes in MVC-ISO force, plasma CK activity, and VAS of muscle soreness • No significant difference in weight, body fat change between interventions • MVC increase with DSE (34 % VS 19 %) than ASE • The magnitude of increase in balance and insulin sensitivity was higher in DSE than ASE
Cho, 2020[20]	South Korea	Randomised cross over study design	To explore the acute effects of stair climbing interruptions during prolonged sitting on vascular and metabolic function after a high-fat meal	12 healthy adults (age: 23.5 ± 2.9 years)	Two interventions 1) a 4-h uninterrupted sitting (sitting trial) or 2) a 4-h sitting interrupted with a 5-min stair climbing (66 % of HRR) every hour after a high fat meal	• Metabolic fitness: TG, glucose concentrations, • Popliteal artery blood flow and shear rate • Measured every hour after a high-fat meal, • Brachial artery FMD @ baseline and end of the session	• Plasma TG and glucose ↑ after a high-fat meal and returned to baseline at the end • Brachial artery FMD ↓ (−1.81 %) in the continued sitting, but not with the stair climb interrupted trial (+0.87 %) • Compared with the sitting trial, the interrupted trial improved popliteal blood flow and shear rate
Chow, 2020[21]	China	Randomized controlled study	To examine the effects of stair exercise on cardiometabolic risk in young obese Chinese females	36 inactive female college students with body fat percentage >30 %, no exercise, no chronic diseases	• Three interventions: (1) descending stairs (DSE); (2) ascending stairs (ASE); (3) control groups • Thrice per weeks, 12 weeks • 1st week − 96 steps × 5 reps/session, progress to 27 reps at 12th week	• DEXA (body fat%, whole-body fat mass, trunk fat mass, abdominal, lower limb fat and muscle mass. • fasting blood glucose, insulin, HOMA-IR, IL-6 and TNF-α. • Enzyme linked immunosorbent assay kits • Before and after 12 weeks	• ↑ Insulin sensitivity 3.5-fold in the DSE group compared with ASE group (−33.2 % vs. −9.8 %). • Proinflammatory factors showed significant decreases in TNF-α (−39.9 % vs. −23.2 %). • Significant reduction in body fat mass was observed for the two exercise groups with no significant difference for the mean values

Donath, 2014[22]	Switzerland	Non-randomised controlled study	To investigate the effects of two 8-week stair-climbing interventions on balance, gait, strength, and endurance in healthy seniors.	48 enrolled but 39 elderly (22 F) completed Aged 61−83 years, BMI 25.08	• Three interventions: (1) one step strategy; (2) 2-step strategy during stair climb training; (3) control groups −three supervised social sessions (bowling, playing billiards, and darts in 8 weeks • 3 sessions/week, 8 weeks • Supervised − garage, 8 floor climbing	• Static balance (force plate), dynamic balance (beam walk), functional reach • Gait (timing gates), strength (double, single leg press) and submaximal endurance before and after 8 weeks	• Did not change maximal strength and explosive power • HR max increased in 2 steps climb group compared to other while HR rest reduced • Balance improved in 2 steps climb group compared to other • Time effects were seen for functional reach but no between group • stair-climbing interventions did not alter static balance, spatiotemporal gait characteristics, and strength performance in healthy seniors
Gay, 2018[23]	United states	Cross-over trial	To determine the effects of 2-min and 4-min bouts of vigorous-intensity stair climbing on glucose levels.	9 overweight/obese adults ranging between ages of 40−64 years with prediabetes and HbA1C levels ranging between 5.7% and 6.4 %	Three interventions: (1) control group; (2) stair-climbing in bouts of 2 min, every hour for 8 h; (3) stair-climbing in bouts of 4 min, followed in every 2 h for 8-h duration.	• Glucose monitored by continuous glucose monitor inserted in abdomen and the finger prick method	• 4 min bout had significant decrease in glucose after 30 min, especially for people with $\geq$90 mg/dl pre exercise glucose levels • 2 min bout effect was similar to control group. • Population with pre-exercise glucose level <90 mg/dl did not show much change in post exercise glucose levels
Jenkins, 2019[24]	Canada	Randomised controlled trial	To explore the effect of stair climbing exercise "snacks" on peak oxygen uptake	• Twenty-four young adults • No known CVD	• vigorously ascending a 3-flights (60 steps), • 3 bouts daily • separated by 1−4 h of recovery, 3 days/week for 6 weeks • Supervised	• Peak O2 uptake and power by incremental cycle protocol	• Peak VO2 ↑ in the climbers compared to controls • VO2peak was higher in the training group compared with control (1918 ± 326 ml/min • Wpeak was also higher in the training group compared with control (178 ± 32 W)
Kennedy, 2007[25]	United Kingdom	Parallel group trial	To investigate the effects of accumulated bouts of stair walking on CRF, BMI and blood lipids in sedentary office workers	• Employees from public sector offices • No known CVD	• Progressive stair climb • Two interventions: (1) stair climb (1 bout/day, 5 days/week, 8 weeks, progressing to 3 climbs gradually; (2) control group • 75 steps/min • Supervised	• Body fat (bioelectrical impedance analysis) • VO2 max (YMCA submaximal cycle test) • Metabolic fitness: TC, TG, HDL, VLDL • Pre and post 8 weeks	• Relative to controls, the stairclimbing group showed a significant increase in predicted VO2max (9.4 %, +2.1 ml/kg/min). • No other significant changes were noted. • modest amounts of stairclimbing may be one of the most time efficient methods of improving and maintaining the health of sedentary individuals.

(*continued on next page*)

Table 2 (*continued*)

Author year	Country	Design	Objective	Population	Intervention	Outcomes	Key findings
Lim, 2020[14]	Canada	Non-blinded parallel group	To compare the effects of 12 wk of usual and stair climbing−based HIIT program on skeletal muscle phenotype in individuals with CAD.	• 20 CVD (18 M, 2 F), undergone recent treatment for CAD • No pacemakers, <2 months cardiac procedures	Randomised to either usual cardiac rehab (30 min at 60%−80% of peak heart rate) or STAIR (three bouts of one flight (12 steps), 3−6 flights/day for 12 wk. 4 weeks of supervised and 8 weeks of unsupervised	• Muscle biopsies of vastus lateralis before, after 4 weeks and after 12 weeks • Fiber cross-sectional area, satellite cell content, and mitochondrial function through immunohistochemistry and western blot test.	• Participants with CAD had a 52 % lower prevalence of Type I fibres and 1$ higher type 2 fibres • No significant differences in type 1 and II fibres after exercise training • Satellite cells increased at 4th week • No differences in capillarisation or myonuclei • Significant increase in phosphorylation and e-NOS at 4th week while no difference at 12th week • The changes are comparable with short time of stair (5 min) vs traditional exercise training (33 min)
McCulley, 1994[26]	United states	Non-randomised controlled trial	to determine the efficacy of stair climb compared with walk/run training, for improving CRF and reducing adiposity	• 19 sedentary, middle-aged male volunteers (40−65 years old) • Free from diseases • 12 for walk or stair while 7 chosen as sedentary controls	• Three interventions: (1) STAIR (StairMaster 4000), (2) WALK; (3) SED for 14 weeks, 3−4 day/week, 30 −45 min/day • 70−80 % of MHR • The training load was gradually increased to 80−85 % MHR at 14th week • Supervised training	• Body density (underwater weighing) and fat% • VO2 max - Incremental treadmill test	• Absolute VO2max increased by 19.6 %in the stair and 19.4 % in the walk/run group, • Relative VO2max increased by 20.1 % and 20.2 % in the stair and walk/run groups, respectively. • Fat mass decreased by ≈ 2.7 kgs in both intervention groups • Body fat % decreased and equal (−2.5 % body fat) in both groups with training.
Meyer, 2010[27]	Switzerland	Single group experimental trial	to evaluate impact of a worksite-based promotional campaign of stair use on cardiometabolic risk in apparently healthy adults	• 77 Healthy employees of university hospital • Aged >18 years, <10 stories/day	• Posters motivating the stair climb posted at 'point of choice' • Campaigns for stair use • 12 weeks • Hospital building (12 stories, 2 floors per story, 10 steps/flight) • Use during working hours	• Physical activity levels by actigraph GT1M • Maximal aerobic capacity (VO2max): Chester step test • Body composition (Bioelectric impedance) • At 0^{th}, 3rd and 6th month	• At 12 weeks, VO2max had increased by 9.2 ± 15.1 % ($P < 0.001$). • BMI (↓ 0.7 ± 2.6 %), fat mass (↓−1.5 ± 8.4 % and waist circumference (↓−1.7 ± 2.9 %) ($P < 0.001$). • Significant decrease of DBP (−1.8 ± 8.9 %,) and a marginal reduction of systolic pressure (−1.3 ± 7.2 %, $P = 0.075$). • LDL cholesterol had decreased by 3.0 ± 13.5 % ($P = 0.026$).

Michael, 2021[7]	Cyprus	Randomized controlled study	To test the effects of walking up and down stairs at home on a range of CVD and MetS risk factors	52 sedentary females (18−45 years) from four different Cyprus companies	• Three interventions: (1) home based stair climb (10 floors of climbing), (2) gym based stair climb (Leekon stair machine − 50 steps/min, 143 steps, 2 −5 bouts/day); (3) control • 5 days a week for period of 8 weeks. • progressed till 5 ascents per day in the last two weeks	• Fat percentage: 7 skinfold • VO2 max: 20 m shuttle run • Leg power: counter movement jump • Metabolic fitness: TC, TG, VLDL, Glucose, HDL	• significantly increased aerobic fitness (VO2 max and lactate) in stir climb group • Slight increase of jump height in CMJ in experimental group ($p \leq 0.01$) • HDL ↑ and VLDL ↓ • Home-based stair climbing was responsible for lowering fasting blood glucose ($p = 0.03$)
Mir, 2017[28]	Malaysia	Non-randomised controlled study	To compare the effectiveness of 4 weeks stair climbing intervention with walking on cardiometabolic outcomes	• 37 young adults (18−25 years) • Healthy with no apparent illness • living a sedentary lifestyle.	• Three interventions: (1) full stair climb (7 floors, 14 flights); (2) half stair climb (3.5 floors, 7 flights) and one-mile treadmill walk • Self-selected speed • Twice day, 5 days a week and 4 weeks	• Physical fitness index from Harvard step test • Absolute VO2 from Astrand Rhyming	• Significant improvement in VO2 max (11.66 ml/kg/min) in full stair climb while no significant difference in other two groups • No statistical difference in the physical fitness index within and between groups • significant reduction ($p < 0.005$) in time taken to complete the intervention in the all three groups
Ozaki, 2019[29]	Japan	Experimental study	To explore the additive effects of stair-climb to routine walk program on muscle thickness and strength.	• 15 elderly participants (age >65 years) • free of any overt chronic disease, • not past or current smokers, • not taking any medications	• Two interventions: (1) walking alone; (2) walking + stair climb • 17 weeks progressive walking (self selected speed initially progressing to 65−80 % HRR during final weeks • Walk + stair group had additional incremental step training	• Muscle thickness of right thigh and lower leg− ultrasound scans • MVC knee extensors and flexors − Takei dynamometer • 10 m timed walk test	• Except lower leg, thigh muscle thickness improved within condition • After 6 weeks, knee flexion and extension strength improved • No interaction effects between group x time was noted • Stair climbing did not provide additional training effects
Paschalis, 2013[30]	Cyprus	Parallel group controlled trial	To compare the effect of two sessions of stair descending versus stair ascending exercise on muscle performance and health-related parameters in young healthy men	• Twenty males • Not taking any medications	• Two interventions: (1) a stair descending group and (2) a stair ascending group • Automatic escalator device • 5 min stair climbing/bout, 5 bouts/day • Speed was set at 60 steps/min	• Creatinine kinase (index of muscle damage) • Isometric knee extensor − isokinetic dynamometer • Blood chemistry: insulin sensitivity, blood lipid profile and redox status • during 1st session and 2nd session interspersed with 3 weeks.	• Significant interaction for ROM, torque and DOMS • Insulin resistance due to muscle damage due to bout 1 • Bout 1 of ascending or descending stair climb causes more muscle damage • Successive stair climbs positively influence insulin sensitivity and lipid profile • stair descending exercise systematically caused greater elevations in insulin sensitivity indices compared to stair ascending exercise.

(*continued on next page*)

Table 2 (*continued*)

Author year	Country	Design	Objective	Population	Intervention	Outcomes	Key findings
Rafiei, 2020[31]	Canada	Randomised cross over study	to investigate brief stair climbing exercise "snacks" could lower postprandial insulin, glucose, and free fatty acids responses during prolonged sitting	N = 22 (12 healthy weight, 11 overweight)	completed two interventions: 1) sedentary (9-h sitting) and 2) stair climbing snacks (8 × 15−30 s once per hour).	• Salivary insulin - total insulin area under the curve	*Healthy weight* • no significant differences between conditions for total (9-h) insulin AUC (P = 0.24, d = 0.4), total glucose AUC (P = 0.17, d = 0.48), total non-esterified fatty acid AUC (P = 0.22, d = 0.4), or total TG AUC (P = 0.72). *Overweight* • total insulin AUC (−16.5 %, P = 0.036, d = 0.94) and total NEFA AUC (−21 %, P = 0.016, d = 1.2) were significantly lower in SS versus SED. • No differences were found for total glucose and triglyceride AUC (all, P > 0.31)
Takaishi, 2012[32]	Japan	Non-randomised cross over study	To explore the effectiveness of stair climb interventions on postprandial glucose in glucose impaired participants	11 healthy participants. Not engaging in regular and strenuous ex.	Two visits: (1) STAIR: stair climbing visit: 80−110 steps/min (moderate intensity corresponding to 60 % HRR and 13 RPE); (2) WALK: self selected walk speed on 650 m course for 2 h for 6 min at 90th min	• Blood glucose, insulin lactate by immunoassay • Energy expenditure by equations	• At 90th min, no diff in glucose levels between WALK and stair • At 105th min, blood glucose levels lower in STAIR compared to WALK • STAIR reduced by 2.5 mmol/dl and WALK reduced by 0.7 mmol/dl • Blood lactate increased after STAIR compared to WALK
Takaishi, 2014[15]	Japan	Narrative review	To summarize the studies that have investigated the effects of stair-ascending exercise	*Inference* • Eight studies (1975−2010). • Work intensity on stairs was found to be similar to that of uphill treadmill walk and loaded bicycle training • Oxygen consumption was estimated for the stair climbing bouts • CRF and metabolic fitness can be improved by accumulating bouts of short-duration exercise with stairs • VO2 for ascending = 33 ml/kg/min while ascending and descending exercise is 19.2 ml/kg/min • 5 min stair climbing exercise reduced the blood glucose concentration by 60 mg/dl (3.3 mmoL/l) • stair climbing improves CVD health and fitness, but should be prescribed for elderly with caution			
Takaishi, 2017[33]	Japan	Experimental cross over trial	to confirm acute effect of stair exercise on postprandial hyperglycaemia by comparing it cycle exercise performed at the same workload	• 7 T2DM and 7 IGT patients • Not having microvascular complications or antihypertensive medications	Two visits: (1) ST-EX: descending stair (60−65 % HRR, RPE − 13−14), 21 steps, 8−10 reps; STEP RATE − 80−110 (2) Bi-EX: 50−60 reps/minute progressing to predetermined workload	• Finger prick glucose • HbA1C antecubital • Lactate at 90 min • 4th day Douglas bag − gas analysis (RER) • Blood glucose insulin - immunoassay	• blood glucose level ↓ between 90 and 105 min after a meal was significantly greater for ST-EX (−4.0 ± 0.7 mmol/L) than for BI-EX (−2.7 ± 0.9 mmol/L). • Serum insulin levels did not differ between the groups.

							• VO2 max for ST-EX was ↑ than that for BI-EX, • Lactate level and RER for ST-EX were ↓ than BI-EX.
Whittaker AC, 2021[8]	Netherlands	Secondary analysis study	to explore the association between stair climbing and the metabolic syndrome.	• 782 participants (423F) • Dutch Famine Birth Cohort	Nurses enquired the exposure of "Do you climb stairs daily?" (yes/no)"	• TG and HDL (enzymatic colorimetric methods) • glucose levels (photometric assay) • waist circumference, BP through sphygmanometer • Composite scores for Metabolic syndrome (MetS)	• who did not climb stairs daily were at greater risk for MetS (OR = 1.90), • the components affected high blood glucose, (OR = 1.73), TG (OR = 1.49) and BP (OR = 1.50).
Yamaji, 2021[34]	Japan	Cross sectional study	To explore the relation between daily stair climbing activity and vascular function	• 374 patients with hypertension (67−73 years) • Underwent health checkup at university	Three groups based on their daily stair climbing habit: no stairs group, climbing stairs to the 2nd-floor group, and climbing stairs to the ≥3rd-floor group	• Endothelial function (FMD): doppler (brachial artery) • Vascular smooth muscle function was assessed through response to nitro-glycerine	• FMD (3.3 %) ↑ in stair group >3 floors compared to stair <2 floors and no stair group • ↓NID seen in no stairs (7.4 %) group compared to < 2 floors (10.9 %) and >3 floors (11.3 %) • Endothelial function impaired in no stair group

Abbreviations: ASE, ascending stair exercise; AUC, area under curve; BMI, body mass index; BMD, bone mineral density; BP, blood pressure; CK, creatinine kinase; CRF, cardiorespiratory fitness; CVD, cardiovascular disease; DEXA, dual X-ray absorptiometry; DOMS, delayed onset muscle soreness; DSE, descending stair exercise; F, female; FMD, flow mediated dilation; HbA1C, glycated haemoglobin; HDL-C, high density lipoprotein cholesterol; HOMA, IR, insulin resistance; HR, heart rate; IL, interleukin; LDL-C, low density lipoprotein cholesterol; M, male; MVC, maximal voluntary contraction; NEFA, non-esterified fatty acids; NID, nitro-glycerine induced dilation; OR, odds ratio; OW, overweight; ROM, range of motion; TG, triglycerides; TC, total cholesterol; TNF, α, tumor necrosis factor; VAS, visual analogue scale; VO2 max, maximal oxygen consumption.

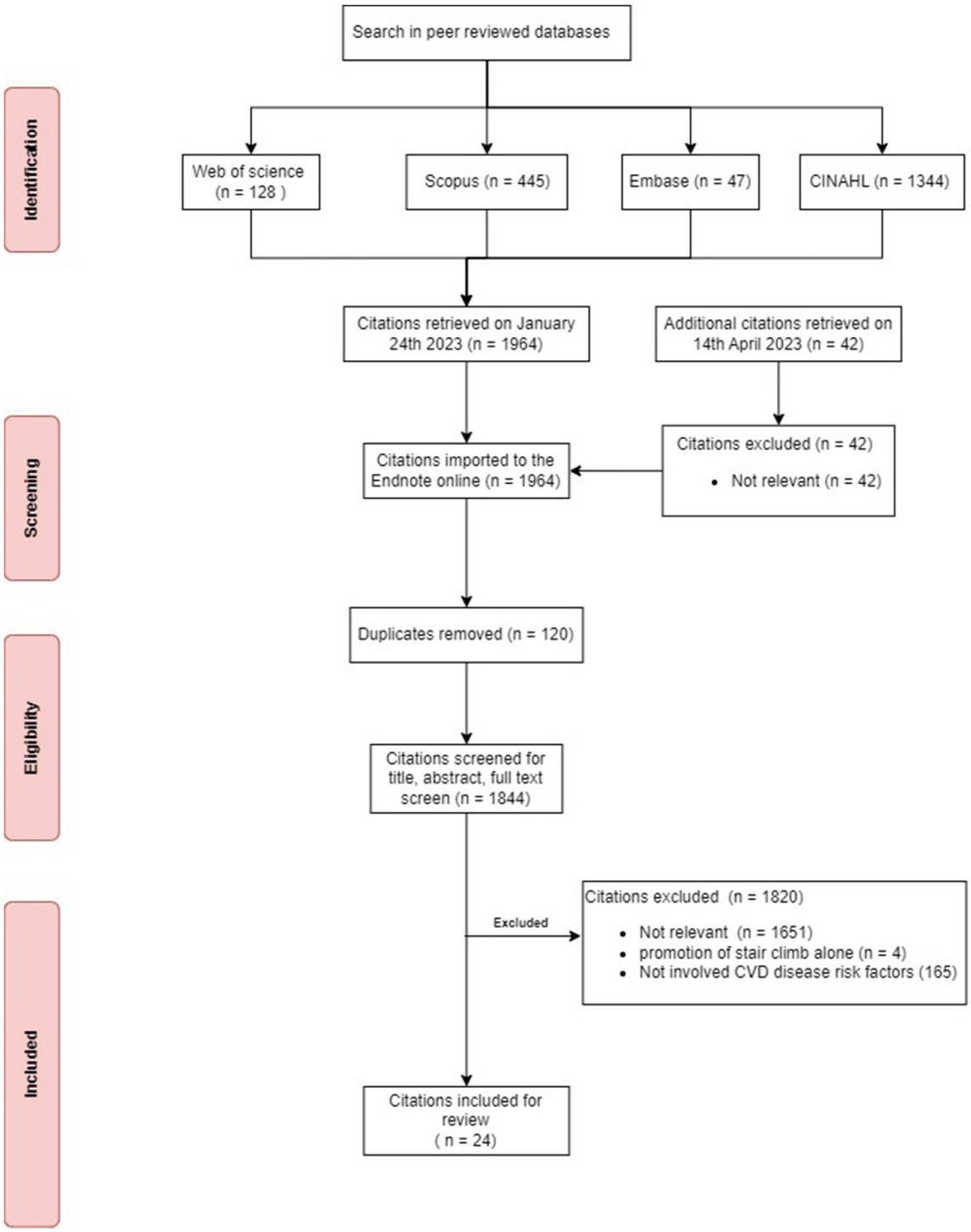

Figure 1: Flowchart showing the screening and inclusion of the eligible articles.

weighing,[26] bioelectric impedance,[25,27] skin fold[7] were rarely administered.

Most studies have found significant changes in cardiometabolic risks ranging from body mass to serum biomarkers (glucose and lipid profile) with stair climb interventions, whether sporadic or continuous bouts. The favourable cardiometabolic effects are higher in the supervised exercise sessions than in home-based stair-climbing interventions.

i. *Cardiorespiratory fitness:* Most studies have found a significant increase in the VO2 max (2−5 ml/kg/min) after the stair climb interventions of >8 weeks duration[7,17] while few failed to observe the change. Stair climbers demonstrated 1.9 L/min higher absolute VO2 and 9 % higher relative VO2 max than the control group.[24,25] However, McCulley 1994 could establish a higher absolute VO2 in stair climbing intervention than controls.[26]

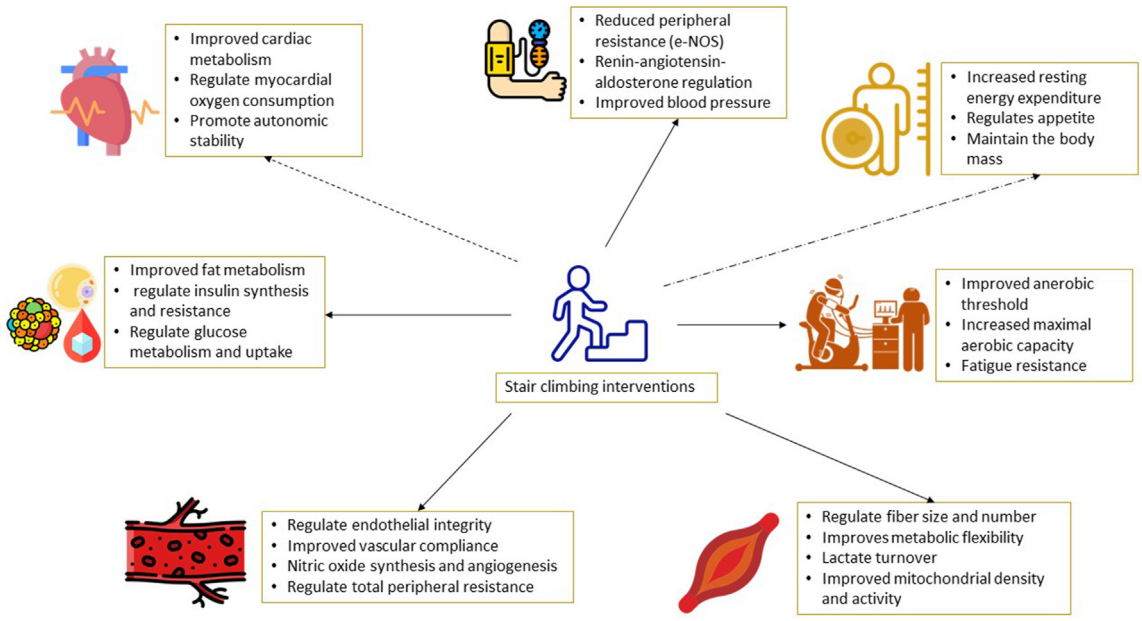

Figure 2: Potential favorable physiological benefits associated with the stair climbing interventions. ⟶ denotes proven positive effects whereas ⟶ denotes proven equivocal effects and ⇢ yet to be proved physiological effects.

ii. *Metabolic fitness markers:* Significant reduction in glucose was observed, especially in people with prediabetes or T2DM.[23] Healthy individuals, too, benefited from the hypoglycaemic effects of stair climb interventions.[32] Insulin sensitivity improved with stair climbing interventions by 24 % compared to walk interventions.[19,21] Area under the curve for insulin and non-esterified fatty acids were found to be reduced by 16 % and 21 % with stair climb interventions. At the same time, no significant difference in glucose was observed.[31]

iii. *Body composition changes:* Most studies found no changes in the body weight or mass with the stair climb interventions.[16,17,19] Significant fat mass changes were observed with stair climb interventions similar to walk interventions.[21]

iv. *Inflammation:* Two studies have explored the inflammatory changes with the stair climbing intervention.[17,18] Interleukins were found to be reduced with stair climbing interventions in obese populations however remained inert in normal-weight individuals and failed to observe changes with TNF-α. However, Chow 2020 found that TNF-α reduced by 40 % after 12 weeks of stair interventions.[21] Further salivary immunoglobulin was found to be high in the active group. No significant changes in homocysteine were found.[18]

v. *Vascular functions:* Blood pressure was significantly lower (−8%) with stair climb interventions.[19] Cho 2020 demonstrated that stair climbing bouts can mitigate a reduction in flow-mediated dilation associated with prolonged sitting, and popliteal shear rate improved in stair climbing interventions.[20] These findings were further strengthened by Yamaji (2021), who found a 3.3 % increase in flow-mediated dilation with stair-climbing interventions. Vasodilator such as e-NOS improved from the 4th week of the training.[14]

vi. *Skeletal muscle functions:* Mixed evidence exists with muscle strength improvements with stair climbing. Chen (2017) found no changes in the maximal voluntary contraction or muscle soreness.[19] Though no change in strength, maximal explosive power and gait parameters were observed, the balance was found to be improved after stair climb interventions.[22] Further, no change can be seen in the fibre type after stair training in coronary artery disease patients was observed. Satellite cells improved in number after stair training compared to controls.[14] Countermovement jump height was found to improve after stair climb.[7] Thigh muscle thickness was found to be improved with stair climb interventions, while no significant changes were noted in lower leg muscle morphology.[29] While contemporary studies favour muscle changes with stair climbing, one study observed muscle damage and soreness after one bout of stair climbing. However, successive stair-climbing training sessions make this muscle damage and soreness insignificant.[30]

Discussion

The present scoping review aimed to provide a breadth of knowledge on the effects of stair climbing on cardiometabolic disease risk. Whether administered as a continuous, sporadic or bouted, the stair climbing interventions are shown to be beneficial and identified as single ammunition to multifaceted cardiometabolic disease risk. Stair climbing interventions appear to improve cardiorespiratory fitness, glycaemic and lipid profiles, regulate energy expenditure and vascular functions.

World Health Organisation recommends a weekly dose of 150 min of moderate-intensity or 75 min of vigorous-intensity

physical activity for achieving health benefits, including protection against cardiometabolic disease risk.[35] Despite these recommendations, a substantial portion of the global population (1 in 4 adults and 3 in 4 adolescents) does not meet the activity recommendations, with an increased risk of cardiovascular disease and economic burden.[36] Public health experts recommend feasible, familiarised and economically viable activity strategies that could be easily integrated into daily lives and reduce the cardiometabolic disease risk. One such intervention is stair climbing.[15]

The studies included in this review consistently reported significant improvements in various risk factors associated with cardiovascular diseases, including blood pressure, cholesterol levels, insulin sensitivity, and body mass. Furthermore, incorporating stair-climbing into daily routines has significantly improved cardiorespiratory fitness. However, the emerging evidence regarding the efficacy of inflammatory markers or body fat percentages is promising. Still, there are no studies yet to explore the effects of stair climbing on cardiac remodelling and dynamics which could further reinforce the need for physical activity in these clinical populations. Figure 2 consolidates the potential favourable physiological effects of stair climbing interventions reviewed from the available literature.

While the majority of studies included in this review found significant changes in cardiometabolic risk factors with stair-climbing interventions, it is worth noting that supervised exercise sessions were found to be more effective than home-based interventions. This suggests that support from trained professionals may benefit individuals looking to incorporate stair-climbing into their exercise routine.

For efficient cardiorespiratory conditioning, short bouts of vigorous-intensity aerobic exercise are speculated to have equal benefits to continuous low-moderate intensity exercise.[37] Stair climbing is a practically feasible, no-cost and familiar intervention that could be integrated into daily life to reap health benefits. Takaishi 2014 claims "net energy cost of stair climbing was similar to 26 % of upslope walking and pedalling bicycle ergometer".[15] In sedentary individuals, even a lesser intensity volume of activity could bring appreciable health benefits, however, to a lesser degree than the bouted moderate–vigorous activity.

Compared to interventions involving walking (≈30 min), similar cardiometabolic health benefits can be reaped from the shorter stair climbing interventions (≈5–6 min).[25] Majority of the studies demonstrated the beneficial effects of stair climbing in multifaceted components of cardiometabolic disease risk in a short period.[15]

Acute intense stair climbing was shown to have minimal adverse effects, such as acute muscle damage and the flare-up of arthritis. In contrast, successive stair climb bouts or training diminish these adverse effects.[30] The stair climbing bouts should be of less volume while initiating the training program (1–2 flight/climb, 1–2 climbs/day, 150 steps) and progressing 1 flight every week) should be a safe zone for healthy sedentary individuals, while the clinical population would benefit from an even lesser dose. Adequate familiarisation, stair height <18 cm, preparticipation risk screening before stair climb interventions would reduce the fall risks or cardiac or musculoskeletal loading associated with stair climbing.

Implications for practice

Due to computerization, manual labour is significantly reduced, and sedentary behaviour and physical inactivity become inevitable in modern society, posing a high risk for cardiometabolic diseases. Public health experts recommend regular physical activity of 30 min daily to mitigate the cardiometabolic disease risk; however, only a fraction of the global population meets the recommended dose of weekly physical activity of 150 min. The challenges in achieving the weekly target of physical activity are attributed to various factors, such as limited access to high-quality gym and fitness centers, the expenses involved in accessing equipment and facilities, the requirement for expert guidance to use fitness equipment and techniques, and difficulties in managing time and travel. These factors collectively make it nearly impractical for individuals to meet their physical activity goals. Workplaces and educational institutions often have staircases, which can serve as a viable and superior alternative for promoting moderate to vigorous physical activity. Our review highlights the potential benefits of stair climbing in ameliorating cardiometabolic disease risk, feasibility and accessibility to the community, making stair climbing an impending fitness source. Our review may aid public health experts, behavioural scientists and policymakers in designing, implementing and advocating stair climbing to reduce society's cardiometabolic disease risk. Further designing and implementing appropriate town planning strategies, such as appealing staircases and implementing optimum stairwell use at public health buildings (malls, worship places) and educational institutions, is the need of the hour.

Recommendations

From the findings of the present scoping review, we reckon further studies to investigate the effects of stair-climbing interventions on specific populations, such as older adults, individuals with chronic diseases, and those with disabilities. Further, sparse studies explored the optimal duration, frequency, and intensity of stair-climbing interventions needed to improve cardio-metabolic outcomes significantly. We recommend future studies that could examine the long-term effects of stair-climbing interventions on cardio-metabolic outcomes and other health-related outcomes. Also, further studies are warranted exploring the potential barriers and facilitators to implementing stair-climbing interventions in community and organizational settings.

Conclusion

Our scoping review provides evidence that stair-climbing interventions have the potential to be a low-cost, feasible, and effective form of physical activity for improving cardiometabolic health outcomes in adults. While supervised exercise sessions are found to be more effective than home-based interventions overall, the feasibility and accessibility of stair-climbing interventions make them an attractive option for individuals looking to improve their cardiovascular health without requiring access to specialized equipment or facilities. These findings suggest that stair-climbing interventions have

great potential as a simple yet effective strategy for reducing the risk factors associated with cardiovascular diseases. Further research is needed to explore these interventions' long-term effects and identify specific populations or settings where they may be especially beneficial.

Availability of the data

All the available data was presented in the study. The main data will be available on reasonable request to the corresponding author.

Source of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

As a scoping review, this work did not require ethical approval.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Author contributions

BC conceived and designed the scoping review. AM and BC searched and collated the citations. BC analyzed and interpreted the data. AM wrote the initial manuscript draft, and BC provided critical input and shaped the manuscript in its current form. All authors critically reviewed and approved the final draft. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Acknowledgment

The authors would like to thank Manipal Academy of Higher Education for the knowledge and research support for the completion of the review.

References

1. Tsao CW, Aday AW, Almarzooq ZI, et al. Heart disease and stroke statistics-2022 update: a report from the american heart association. **Circulation 2022**; 145: e153–e639.
2. Amini M, Zayeri F, Salehi M. Trend analysis of cardiovascular disease mortality, incidence, and mortality-to-incidence ratio: results from global burden of disease study 2017. **BMC Publ Health 2021**; 21: 401.
3. Khan H, Kunutsor S, Rauramaa R, et al. Cardiorespiratory fitness and risk of heart failure: a population-based follow-up study. **Eur J Heart Fail 2014**; 16: 180–188.
4. Mora S, Cook N, Buring JE, Ridker PM, Lee IM. Physical activity and reduced risk of cardiovascular events: potential mediating mechanisms. **Circulation 2007**; 116: 2110–2118.
5. Napolitano MA, Tjaden AH, Bailey CP, DiPietro L, Rimal R. What moves young people? Applying the risk perception attitude framework to physical activity behavior and cardiometabolic risk. **Transl Behav Med 2022**; 12: 742–751.
6. Sanchez-Lastra MA, Ding D, Dalene KE, del Pozo Cruz B, Ekelund U, Tarp J. Stair climbing and mortality: a prospective cohort study from the UK biobank. **Journal of Cachexia, Sarcopenia and Muscle 2021**; 12: 298–307.
7. Michael E, White MJ, Eves FF. Home-based stair climbing as an intervention for disease risk in adult females; a controlled study. **Int J Environ Res Publ Health 2021**; 18: 1–14.
8. Whittaker AC, Eves FF, Carroll D, et al. Daily stair climbing is associated with decreased risk for the metabolic syndrome. **BMC Publ Health 2021**; 21: 923.
9. Wu Y, Luo M, Tan X, Chen L. Stair climbing, genetic predisposition, and the risk of incident type 2 diabetes: a large population-based prospective cohort study. **J Sport Health Sci 2022**; 12: 158–166.
10. Allison MK, Baglole JH, Martin BJ, MacInnis MJ, Gurd BJ, Gibala MJ. Brief intense stair climbing improves cardiorespiratory fitness. **Med Sci Sports Exerc 2017**; 49: 298–307.
11. Mat Azmi ISM, Wallis GA, White MJ, Puig-Ribera A, Eves FF. Desk based prompts to replace workplace sitting with stair climbing; a pilot study of acceptability, effects on behaviour and disease risk factors. **BMC Publ Health 2022**; 22: 1–9.
12. Hongu N, Shimada M, Miyake R, Nakajima Y, Nakajima I, Yoshitake Y. Promoting stair climbing as an exercise routine among healthy older adults attending a community-based physical activity program. **Sports (Basel) 2019**; 7.
13. Dunford EC, Valentino SE, Dubberley J, et al. Brief vigorous stair climbing effectively improves cardiorespiratory fitness in patients with coronary artery disease: a randomized trial. **Front Sports Act Living 2021**; 3:630912.
14. Lim C, Dunford EC, Valentino SE, et al. Both traditional and stair climbing-based hiit cardiac rehabilitation induce beneficial muscle adaptations. **Med Sci Sports Exerc 2021**; 53: 1114–1124.
15. Takaishi T, Ishihara K, Shima N, Hayashi T. Health promotion with stair exercise. **The Journal of Physical Fitness and Sports Medicine 2014**; 3: 173–179.
16. Andersen LL, Sundstrup E, Boysen M, Jakobsen MD, Mortensen OS, Persson R. Cardiovascular health effects of internet-based encouragements to do daily workplace stair-walks: randomized controlled trial. **J Med Internet Res 2013**; 15: e127–e.
17. Boreham CA, Wallace WF, Nevill A. Training effects of accumulated daily stair-climbing exercise in previously sedentary young women. **Prev Med 2000**; 30: 277–281.
18. Cabral-Santos C, Rafiei H, Lira FS, Little JP. 1288-pub: acute inflammatory response of breaking up prolonged sitting with stair climbing exercise snacks. **Diabetes 2021**; 70: 1288. PUB.
19. Chen TC, Chung-Chan H, Kuo-Wei T, Chih-Chiao H, Kazunori N. Effects of descending stair walking on health and fitness of elderly obese women. **Med Sci Sports Exerc 2017**; 49: 1614–1622.
20. Cho MJ, Bunsawat K, Kim HJ, Yoon ES, Jae SY. The acute effects of interrupting prolonged sitting with stair climbing on vascular and metabolic function after a high-fat meal. **Eur J Appl Physiol 2020**; 120: 829–839.
21. Chow BC, Li S, Zhu X, et al. Effects of descending or ascending stair exercise on body composition, insulin sensitivity, and inflammatory markers in young Chinese women with obesity: a randomized controlled trial. **J Sports Sci 2021**; 39: 496–502.

22. Donath L, Faude O, Roth R, Zahner L. Effects of stair-climbing on balance, gait, strength, resting heart rate, and submaximal endurance in healthy seniors. **Scand J Med Sci Sports 2014**; 24: E93–E101.
23. Gay JL, Buchner DM, Erickson ML, Lauture A. Effect of short bouts of high intensity activity on glucose among adults with prediabetes: a pilot randomized crossover study. **Diabetes Res Clin Pract 2018**; 141: 168–174.
24. Jenkins EM, Nairn LN, Skelly LE, Little JP, Gibala MJ. Do stair climbing exercise "Snacks" Improve cardiorespiratory fitness? **Appl Physiol Nutr Metabol 2019**; 44: 681–684.
25. Kennedy RA, Boreham CA, Murphy MH, Young IS, Mutrie N. Evaluating the effects of a low volume stairclimbing programme on measures of health-related fitness in sedentary office workers. **J Sports Sci Med 2007**; 6: 448–454.
26. McCulley C, Houmard JA, Bruner RK, McCammon MR, Hortobagyi T, Israel RG. Comparison of stair-step ergometry and walk/run training. **Sports Med Train Rehabil 1994**; 5: 107–114.
27. Meyer P, Kayser B, Kossovsky MP, et al. Stairs instead of elevators at workplace: cardioprotective effects of a pragmatic intervention. **Eur J Cardiovasc Prev Rehabil 2010**; 17: 569–575.
28. Mir IA, Yu VLK, Jia FS, Bhat AH. Comparison between stair climbing and 1 mile walking in relation to cardiorespiratory fitness among sedentary adults. **IFMBE Proceedings 2017**; 58: 14–18.
29. Ozaki H, Nakagata T, Yoshihara T, et al. Effects of progressive walking and stair-climbing training program on muscle size and strength of the lower body in untrained older adults. **J Sports Sci Med 2019**; 18: 722–728.
30. Paschalis V, Theodorou AA, Panayiotou G, et al. Stair descending exercise using a novel automatic escalator: effects on muscle performance and health-related parameters. **PLoS One 2013**; 8:e56218.
31. Rafiei H, Omidian K, É Myette-CÔTÉ, Little JP. Metabolic effect of breaking up prolonged sitting with stair climbing exercise snacks. **Med Sci Sports Exerc 2021**; 53: 150–158.
32. Takaishi T, Hayashi T. A short bout of stair climbing-descending exercise ameliorates postprandial hyperglycemia more efficiently than a bicycle exercise. **Diabetes 2012**; 61: A184–A185.
33. Takaishi T, Hayashi T. Stair ascending–descending exercise accelerates the decrease in postprandial hyperglycemia more efficiently than bicycle exercise. **BMJ Open Diabetes Research and Care 2017**; 5.
34. Yamaji T, Harada T, Hashimoto Y, et al. Stair climbing activity and vascular function in patients with hypertension. **Hypertens Res 2021**; 44: 1274–1282.
35. Bull FC, Al-Ansari SS, Biddle S, et al. World health organization 2020 guidelines on physical activity and sedentary behaviour. **Br J Sports Med 2020**; 54: 1451–1462.
36. Amini H, Habibi S, Islamoglu AH, Isanejad E, Uz C, Daniyari H. Covid-19 pandemic-induced physical inactivity: the necessity of updating the global action plan on physical activity 2018-2030. **Environ Health Prev Med 2021**; 26: 32.
37. Garber CE, Blissmer B, Deschenes MR, et al. American college of sports medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. **Med Sci Sports Exerc 2011**; 43: 1334–1359.

How to cite this article: Ghosal AM, Chandrasekaran B. Stair-climbing interventions on cardio-metabolic outcomes in adults: A scoping review. J Taibah Univ Med Sc 2024;19(1):136–150.