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Use of a Simple Stair-Climbing Test to Assess Cardiopulmonary Fitness in Clinical Practice. An Overview of the Published Literature Aiming for a Future Goal

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Abstract: (1) Background: Cardiorespiratory fitness (CRF) is a prognostic factor regarding long time morbidity and mortality. To assess CRF the well-known gold standard is cardiopulmonary exercise testing (CPET), which is a time consuming and expensive test. Therefore, alternative methods for routine evaluation of CRF are needed for the general population as well as for specific patient groups such as children and young adults with congenital heart disease. The Stair Climbing Test (SCT) is a simple and resource saving test reported in the current literature. This test is used in various settings to assess different health associated risk factors including cardiorespiratory fitness, muscular resilience, therapy effectiveness or pre- and postoperative morbidity and mortality. Objectives: To summarize the current knowledge on the use and the different protocols of the SCT in the medical context. Method: An internet-based literature search for research articles on both clinical trials and controlled randomized trials containing the SCT was undertaken. Results: We used Pub Med and Google Scholar for literature research. A total of 200 articles were included. The SCT is used for multiple purposes on various patient groups. Significant correlations to the results from established clinical tests such as spiroergometry and 6-minute walking test were shown repetitively. However, the SCTs were conducted and evaluated in various, not standardized ways. Conclusion: The SCT is a simple, cost saving test with promising reliability for the assessment of physical and cardiorespiratory fitness. Due to its easy approach, it can be used for various objectives, such as the general fitness and for specific patients-groups (i.e. children and young adults with congenital heart disease). Unfortunately, the SCT is not universally accepted yet due to the missing standardization. This standardization of the SCT protocol is however required to establish the SCT as a comprehensive test in the medical field.

Keywords: stair climbing test; cardiorespiratory fitness; exercise test; children; congenital heart disease

1. Introduction

1.1. Health-associated significance of cardiorespiratory- and physical fitness

During the last decades medicine and health care has significantly changed. Prevention is gaining more and more significance. Today it is generally accepted that cardiorespiratory fitness (CRF) is another important risk factor regarding cardiovascular disease, morbidity and mortality. The

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higher the level of CRF, the lower the mortality rate. [1] CRF not only reduces the risk of the occurrence of obvious diseases such as cardiovascular disease or comorbidities like high blood pressure and atrial fibrillation but is also playing an increasingly important role in other areas such as cancer prevention. [2,3]

Therefore, current WHO recommendations suggest a physical activity level for different age groups, e.g. for adults, including at least 150–300 minutes moderate-intensity aerobic physical activity or alternatively at least 75–150 minutes of vigorous-intensity aerobic physical activity per week. Physical activity is defined as any movement, that increases the resting metabolic rate. Nevertheless, a lot of people do not meet these recommendations. Especially in adolescents the recommendations are not fulfilled.[4]

This is of raising concern since the cornerstones of a healthy, active lifestyle are placed in early childhood. Furthermore, this is even more important in people with congenital diseases, for instance children and adolescents with congenital heart disease. [5] As the consequences of a sedentary lifestyle such as metabolic syndrome, diabetes mellitus, cardiovascular disease and others might reduce quality of life severely in these patient groups and increase overall health care costs, it is important to assess and evaluate cardiorespiratory fitness levels more often, preferentially as a routine check-up.

Cardiorespiratory fitness defines the ability of the lungs and the cardiovascular system to supply the skeletal musculature with oxygen during physical activity.

If measured and interpreted accurately, the level of an individual´s CRF can play an important role in the serious decision-making process for prevention and treatment plans. It could even be the decisive factor to evaluate whether the patient receives curative or palliative therapy.[6,7]

Physical fitness defines the performance of the lungs, heart and skeletal muscles, therefore physical fitness testing actually includes the whole body and evaluates not only cardiorespiratory fitness but also, for example psychoneurological- or skeletomuscular function and mobility. [8]

1.2. Established tests for the evaluation of cardiorespiratory- and functional exercise capacity in the medical context

Currently, the clinical gold standard for evaluating cardiorespiratory fitness is cardiopulmonary exercise testing (CPET).[6,7] CPET evaluates the body's overall response to physical exertion and therefore incorporates several organ systems. [9]

In the standard usage, CPET is used as a maximum exercise test, it involves progressively increasing exercise intensity until reaching exhaustion or encountering symptoms or signs that impose limits. [10] Bicycle ergometer and treadmill are usually used for the physical exercise. [11]

While previously used clinical fitness tests such as bicycle ergometry simply recorded vital parameters including pulse, blood pressure and oxygen saturation, CPET adds a ventilatory expired gas analysis to these values. [7] By measuring the peak oxygen uptake (VO2), CPET accurately identifies the highest exercise capacity of the person examined. [12]

Nevertheless, CPET currently is not used in routine check-ups, as it is a costly and time-consuming examination, which requires special equipment and trained health care professionals. It is not universally available and often limited to special institutions.

The other commonly utilized test for evaluation of the functional exercise capacity is the 6-min walk test (6MWT). [13] For the 6MWT the patient is tasked with walking (along a 30-meter route) for 6 minutes, aiming to cover the maximum distance achievable. The key metric assessed is the 6-minute walk distance (6MWD), measured in meters.[13] Three major advantages of the 6-minute walk test are that it is easy to perform, that patients usually tolerate it well and that it is inexpensive.[14]

Particularly the ease with which the 6MWT can be performed and the good tolerance of patients makes it suitable for patient groups with limited fitness such as patients with heart failure. [14]

Nevertheless, it must be considered, that the 6MWT is a submaximal exercise test for most patients. Only in patients with a significantly reduced CRF it can be used as a maximum exercise test.

Currently there is no cheap, universally available maximum exercise test to assess cardiorespiratory fitness. With the gaining importance of the cardiorespiratory fitness level regarding

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preventive and therapeutic approaches, a lot of working groups investigate alternative approaches such as the Stair-Climbing-Test (SCT).

The SCT is used in various approaches and can give a lot of information about an individual's general fitness, as well as its CRF and its motor function. Depending on its approach it also can differentiate between a loss in strength and a lack of coordination as well as whether there is a respiratory or cardiological restriction.

The aim of this review is to give an overview and compare the different SCT approaches used so far.

2. Materials and Methods

2.1. Search strategy

We conducted an internet-based literature search. For this purpose, we primarily used Pub Med as well as Google Scholar and the Cochrane Library to cross check. The search terms "stair climbing test OR stair-climbing test" was used on Pub Med to find original research articles on the topic. (The search was last conducted on January 03rd 2024) A total of 973 articles matched our initial searching criteria.

2.2. Inclusion Criteria

Randomized controlled trials, clinical trials and pilot studies, available as full text in English language that used the SCT in any form and described its use and implementation were included. Our literature search was not restricted to an age group.

2.3. Exclusion Criteria

We excluded articles that were not relevant to our research question, review articles, meta-analysis and articles that were only available as abstracts. Studies that used the SCT but did not describe the exact application and design were also eliminated.

2.4. Data Extraction

Of the 973 articles that matched our initial inclusion criteria on Pub Med, 319 mentioned the SCT and were accessible as full text. Ultimately, 200 of them matched our final inclusion criteria and were therefore included in our review. The others were discarded because they either mentioned the SCT but did not describe its implementation in more detail, or they were not original texts, or because they were not thematically relevant to our research question.

3. Results

In the Pub Med search a total of 200 articles matched the final searching criteria, described the usage of the stair climbing test and were therefore included in this review.

In these 200 trials the SCT was used with different intentions and for the evaluation of various body functions. They were performed between 1986 and 2023. The most frequently investigated parameter during SCT was physical and neuromuscular function. (Table 1) Cardiorespiratory fitness and exercise tolerance was evaluated in a smaller number of trials (Table 2). Some studies evaluated additional effects such as blood sugar, the ability of complex thinking and others (Table 3).

Moreover, the SCT was performed in various ways. In some trials the test was conducted with 10 steps or more. Most studies evaluated the ascending as well as the descending, others either or. The measured parameters differed a lot as well. With a total of 122 studies, the majority used the time needed to complete the SCT as the only recorded result, the total distance however varied. In only a few trials, other parameters were collected, including vital signs or the number of steps climbed. Several studies calculated the so-called stair-climbing power or VO2max of the collected values.

Some trials even showed, that the SCT can be a part of physiotherapy. Khan et al. for instance integrated stair climbing with and without audio feedback into the physiotherapy of 17 children with

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different diagnoses and then investigated whether the use of audio feedback made a difference to the outcome during SCT. [15]

Overall, there is no standardization of the SCT and therefore its clinical use is not clearly recorded. The SCT has been used in completely different ways to evaluate different body functions. The implementation varied in the number of steps that patients had to climb, the parameters collected, the questions to be answered with the SCT, permitted aids during the test and the information that patients received before the test. All these aspects varied significantly and were not standardized.

3.1. Outcome

3.1.1. Physical and neuromuscular function (and mobility)

Physical function is one of the commonly examined parameters when using the SCT. 155 of the included studies used the SCT to evaluate physical function of participants or patients. (Table 1)

Patients with orthopedic- or muscular conditions

The examined participants often had an orthopedic intervention and were in various stages of rehabilitation. Heiberg et al. for instance evaluated the effect of a walking skill training program in 68 patients who had undergone a total hip arthroplasty and used the SCT for measuring physical function 3 months post operation. [16] Other working groups also used a form of SCT to evaluate physical or motor function in patients with knee or hip arthroplasty, either to compare capacity before and after surgery, others to evaluate a special treatment. [17–51] Judd et al. compared patients with knee and hip replacement. They showed that functional performance and muscle strength recovery differ after total knee and total hip replacement. [52]

Another patient group in which a form of the SCT was applied repetitively are patients with knee or hip osteoarthritis. The SCT in these patients was also used to evaluate different treatment approaches for instance Kovacs et al. evaluated the effect of thermal water in patients with osteoarthritis. [53] Kraemer et al. examined the effect of a treatment combination in patients with osteoarthritis [54], whereas Laufer et al. assessed the effect of pulsed short-wave diathermy on pain and function of subjects with osteoarthritis of the knee. [55] Other studies also used the SCT in patients with osteoarthritis to evaluate physical or motor function. [27,56–80]

Other orthopedic patients were also analyzed using a SCT. For example, Beckman et al. assessed physical function in patients after hip fracture.[81] Moreover Adunsky et al. evaluated MK-0677 (ibutamoren mesylate) for the treatment of patients recovering from hip fracture with a SCT. [82] Ljungquist et al. evaluated physical performance in patients with spinal pain. [83] Smeets et al. used the SCT to test physical capacity tasks in chronic low back pain patients. [84,85] Mengshoel et al. assessed physical function in patients with rheumatoid arthritis and ankylosing spondylitis. [86] Wetzel et al. used the SCT to examine functional lower-extremity strength power in patients with multiple sclerosis. [87] Nunes et al. assessed people with patellofemoral pain regarding their functional performance, in correlation to hip muscle capacity. [88] Alfano et al. used the SCT to evaluate the correlation of knee strength to functional outcomes in Becker muscular dystrophy. [89] Collado-Matteo et al. used the SCT to assess the performance of women with fibromyalgia. [90] Schwid et al. assessed the effect of sustained release of 4=aminopyridine on motor function as a symptomatic treatment of multiple sclerosis. [91] Suslov et al. evaluated the efficacy and safety of hydrokinesitherapy in patients with dystrophinopathy. [92]

Follow-up after Cerebrovascular accidents

Apart from orthopedic and surgical patients the SCT was also used to evaluate physical and motoric function in neuromuscular patients as for instance patients after stroke.

Katz-Leurer et al. examined neurological patients with cerebrovascular accident, using a SCT. [93] Lee et al. used the SCT in patients after stroke to assess physical function, Mustafaoglu et al. assessed the effects of body weight-supported treadmill training on static and dynamic balance in stroke patients. [94,95] In another study they also evaluated the mobility of stroke patients using a SCT. [96] Ahmed Burq et al. assessed the effect of whole-body vibration on obstacle clearance and stair negotiation time in chronic stroke patients. [97] Ihl et al. evaluated a multimodal prevention program after transient ischemic attack or minor stroke. [98] Other working groups also used the SCT to investigate patients after stroke for instance the effect on physical performance of strength- or other training approaches. [99–102] Van de Port et al. examined the effect of circuit training compared with usual physiotherapy in 126 patients with stroke. The SCT combined with a stand-up and go test was utilized to evaluate functional mobility. [103]

Furthermore, the SCT was also used to examine children with cerebral palsy (CP). Zaino et al. used a timed SCT to assess 47 children aged 8-14 years, 27 of them with CP. [104] Bar-Haim et al. also assessed children with CP with the SCT. [105]

Obesity and weight reduction

Apart from the approaches mentioned above, the SCT was also used repeatedly to assess obese individuals, for example after weight reduction. Sartorio et al. assessed the effect after a short-term body mass reduction program in obese subjects on their motor function. [106] Grant et al. had a similar approach and assessed the effect of exercise training in obese women. [107] Bayartai et al. evaluated the changes in the Oswestry Disability Index after a 3-week in-patient multidisciplinary body weight reduction program in adults with obesity. [108] Bittel et al. assessed physical function in obese adults with type 2 diabetes mellitus and peripheral neuropathy, using a SCT. [109] Maffiuletti et al. examined the reproducibility of clinician-friendly physical performance measures in individuals with obesity using a SCT. [110] Sousa-Goncalves et al. evaluated the acute effects of whole-body vibration alone or in combination with maximal voluntary contractions on cardiorespiratory, musculoskeletal, and neuromotor fitness in obese male adolescents. [111] Tamini et al. evaluated the acute effects of whole-body vibration exercises at 2 different frequencies versus an aerobic exercise on some cardiovascular, neuromotor and musculoskeletal parameters in adult patients with obesity. [112] Rigamonti et al. assessed the impact of a three-week in-hospital multidisciplinary body weight reduction program on body composition, muscle performance and fatigue in a pediatric obese population with or without metabolic syndrome. A SCT was used to assess the effect on maximal anaerobic power. The protocol covered a staircase with a total height of 1,99m. The SCT could detect effects of the program. They could show a significant reduction in SCT-time in all groups. Whereas patients with metabolic syndrome profited even more than obese individuals without metabolic syndrome. Younger individuals also profited more than older ones. [113] Lazzer et al. also examined the effect of a 3-week inpatient bodyweight reduction program in obese individuals. The SCT was used to evaluate maximum anaerobic exercise capacity. The protocol also covered a total height of 1,99m. They could show that baseline SCT-time was significantly lower in males, compared to females. After the 3-weeks SCT time decreased significantly solely in females. [114] Usubini et al. used the SCT to assess maximum anaerobic power in obese patients before and after a 3-week multidisciplinary weight reduction program. The SCT protocol used, covered a total height of 1,99m. The test was performed at the fastest possible time and power was calculated according to the following formula: (bodyweight × 9:81 × 1.99) /SCT time. They could show a significant reduction in SCT time after the program. [115]

Endocrine factors

With gaining interest, the SCT was also used to evaluate the effect of testosterone or androgens on physical function. Knapp et al. examined the effects of a supraphysiological dose of testosterone on physical function, muscle performance, mood, and fatigue in men with HIV-associated weight loss. [116] Nilsen et al. evaluated the effects of strength training on body composition, physical functioning, and quality of life in prostate cancer patients during androgen deprivation therapy. [117] Storer et al. assessed the effects of testosterone supplementation for 3 years on muscle performance and physical function in older men. [118] Gagliano-Juca et al. showed that testosterone does not affect agrin cleavage in mobility-limited older men despite improvement in physical function, using a SCT. [119] Sattler et al. and Travison et al. assessed the effect of testosterone on physical function, using a SCT. [120,121] Glavao et al. used the SCT in patients with prostate cancer to assess the effect of exercise on treatment side effects. [122]

Chikani et al. evaluated the impairment of anaerobic capacity in adults with growth hormone deficiency. [123]

Age and the elderly

Another approach for the SCT was to use it so assess mobility and physical function in otherweise healthy elderly. [118,124–152] Chalé et al. for example investigated the efficacy of whey protein supplementation in 80 mobility-limited older adults, using the SCT among other tests to evaluate physical function. [153] Daly et al. examined the effects of a multinutrient-fortified milk drink combined with exercise on functional performance, muscle strength etc. in middle-aged women. [154]

Ke et al. assessed the reliability of a SCT to assess physical function and coordination in children aged 2-3. [155]

Patients of internal medicine and general surgery

Lanzi et al. examined functional performance during a 3-month supervised exercise training program in patients with symptomatic peripheral artery disease, using a SCT. [156]

Molsted et al., Storer et al. and Zhang et al. used the SCT in patients with hemodialysis to assess the effect of an exercise training on physical function [157–159]

Dreher et al. used the SCT in patients with COPD. [160]

Reddy et al. used a SCT to predict perioperative complications in patients undergoing abdominal surgery. [161]

Healthy adults

Apart from being used in special patient groups, the SCT is also used to assess therapy effects and health preventive approaches in healthy adults.

Basaria et al. evaluated the safety, pharmacokinetics, and effects of LGD-4033, a novel nonsteroidal oral, selective androgen receptor modulator, in healthy young men. [162] Baldwin et al. also examined healthy adults with a SCT regarding musculoskeletal symptoms. [163,164]

Mulla et al. evaluated the effects of lower extremity strengthening delivered in the workplace on physical function and work-related outcomes among desk-based workers. [165]

3.1.2. Cardiorespiratory fitness / exercise capacity

Cardiorespiratory fitness and exercise tolerance are the second most important function assessed with the SCT. 37 of the included trials examined cardiorespiratory fitness (Table 2); It could be outlined that the results in SCT showed a significant correlation to CPET-parameters, maximum heart and respiratory rate e.g. Pollok et al. [166] The participants in the trials, evaluating CRF and exercise capacity, were also orthopedic patients, patients before/after lung transplantation and patients with chronic lung diseases for instance chronic airflow obstruction. For example, Elbasan et al. examined children with cystic fibrosis. [167] Moreover, there were several studies in healthy adults, for instance sedentary young women, or obese females. [168,169] Sartorio et al. examined obese children and adolescents. [170] Devendra et al. examined adults with newly diagnoses persistent foramen ovale with a SCT to assess deoxygenation. [171] Hetzler et al. used a SCT in American football athletes.[172]

Pulmonary patient groups

Mc Keon et al. evaluated the effect of inspiratory resistive training on patients with severe chronic airflow limitation. To assess exercise endurance, they used the SCT in addition to other exercise tests to determine the influence of the specific training on different types of exercise. The SCT did not follow a predefined protocol. The number of stairs completed by the patient at a normal rate under the supervision of a physiotherapist were recorded without a time limit and the test ended when symptoms of breathlessness or weakness occurred. [173]

Pollock et al. investigated if a SCT can be used to estimate VO2max in patients with chronic airway obstruction (CAO). The SCT was conducted as a symptom limited SCT with a maximum of 10 flights, most patients achieved at least 4 flights=13,3m height. The test was conducted twice. A resting gas sample and a gas sample during exercise was collected. VO2, CO2 output, minute ventilation (VE), and tidal volume were calibrated using standard techniques. The subject's blood pressure, pulse, and respiratory rate were measured at rest and immediately after the test. Saturation

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and heart rate was measured throughout the test. The results in CPET were compared to those achieved in bicycle CPET. The number of steps climbed, correlated well with peak VO2. They could show a linear correlation between peak VO2 for stair climbing and cycle ergometry. Whereas VO2max, HR, RR, BP were higher during SCT as in CPET. According to their results, the study shows that 1-2 flights of stairs is not exhausting enough. Nevertheless, considering this, the study implies that the SCT can be used to estimate VO2max. [166]

Elbasan et al. assessed the effects of chest physiotherapy and aerobic exercise training on physical fitness in children with cystic fibrosis. 16 patients between 5-13 years were examined. All children were assessed at the beginning and the end of a 6-week training. A 10-step SCT was conducted, as well as bicycle CPET. They could detect a positive effect on anaerobic power and speed, which was reflected in the results of SCT and CPET. [167]

Lung resection

Pate et al. assessed patients with non-small lung cancer. In this patient group it is stated to be often difficult to decide whether a surgical resection is possible or not, especially in cases with coexisting chronic airway obstruction or ischemic heart disease. They used a symptom limited protocol for SCT. A stair climb of 3 flights or more was was associated with reduced postoperative morbidity and therefore a proof for lobectomy, or 5 flights or more for pneumonectomy. The flight height was not standardized. [174]

The working group Brunelli et al. conducted several studies, using a SCT to assess cardiopulmonary fitness/aerobic capacity and oxygen consumption preoperative in patients considered for surgical lung resection. After a cardiovascular evaluation and a spirometry with assessed carbon monoxide diffusion capacity, a predicted postoperative lung function was calculated. Values below 60% indicated further testing. Therefore, a SCT or 6MWT was used. The SCT protocol covered a total of 16 flights, patients were asked to climb at a pace of their choice and stop for exhaustion or symptoms like dyspnea. An achieved altitude >12m was considered satisfying and surgery was offered. Operative morbidity and mortality using this SCT cut-off values were comparable to the data collected with full CPET. They showed a significant correlation between VO2max and the climbed altitude. In patients with a predicted postoperative function <30%, CPET was indicated. In another study of this working group, they even stated that a reached altitude of >12m was the only predictor of cardiopulmonary complications. Patients, unable to climb 12m, had a 2.5 to 13fold higher risk for cardiopulmonary complications and mortality, compared to those climbing >22m. An achieved altitude of >18m was significantly correlated with long-term survival. This working group also calculated stair climbing work, VO2max, oxygen-pulse, using the following formula: Work = (height of the step in meters x steps per minute x body weight in kilograms x 0.1635). VO2 max in milliters per minute =(5.8 x body weight in kilograms + 151 + 10.1 x work). Maximum oxygen pulse = (VO2 max/maximum heart rate). [175–182]

Koegelenberg et al. performed another preoperative study in patients with considered lung resection. The used symptom limited SCT protocol in this study covered a total of 20 m vertical height. Patients were asked to climb as fast as possible. The altitude reached and the average speed was compared to VO2max during bicycle CPET. They could show that the average climbing speed was an accurate semiquantitative predictor of VO2max/kg. [183]

Pancieri et al. used a SCT protocol, covering a total height of 12,16m to examine patients before and after lung resection. As they did before in their working group with Cataneo et al. 40 patients were included. The time needed to complete the stair climb was recorded and the number of functioning lung segments planned for resection, used to predict postoperative test results. The aim was to find an easy exercise test to predict if the patient could tolerate the surgery. [184,185]

Bernasconi et al. compared SCT to treadmill CPET to define cut-off values for lung resection. 56 patients were examined. The SCT protocol included a maximum height of 20m. A portable spirometry was used. The patients reached a mean altitude of 16,9m. 22 patients did not reach 20m. VO2max differed not significantly between SCT and treadmill CPET. Speed of climbing was significantly associated with VO2 max. The group stated that patients climbing 20m with a speed of 15 m/min, are eligible for surgery. [186]

Refai et al. investigated the max. inspiratory and exspiratory pressure generated in the mouth before and after SCT in 283 patients before lobe- or pneumectomy. 61% of the patients experienced a reduction in PImax. It showed that a precticted loss of >10% was associated with complications. [187]

Ito et al. retrospectively analyzed data of 65 old people with non-small cell lung cancer and lobectomy. They used a SCT protocol, covering a total of 18m, 5 flights. They could show that patients without desaturation >4% were eligible for lobectomy. [188]

Kubori et al. compared a SCT with the 6MWT in patients before and after lung resection. The SCT was more sensitive than the 6MWT to detect changes in CRF. The used SCT protocol covered a symptom limited SCT with a maximum of 36 flights. The patients reached a mean altitude of 26.3m before and 18.2 meters 4 weeks after lung resection. The difference in the distance reached in the 6MWT before and after resection was not significant. [189]

Nakamura et al. also evaluated patients before and after lung resection, using a SCT. They evaluated if a desaturation of 4% during the SCT could predict complications after lung resection. The symptom limited SCT protocol covered 6 flights with a total height of 22.2m. They could show that patients who underwent the SCT without desaturation had a normal risk for postoperative complications, whereas patients with a desaturation had a higher rate of complications. [190]

Ozeki et al. also evaluated patients with stage I lung cancer before and after lung resection with a SCT to predict whether postoperative exercise capacity will probably be severely reduced or not. The used symptom limited SCT protocol included a total height of 12m. The test was performed at the fastest possible time. Estimated VO2max was calculated, according to Cataneo et al. Patients with complications needed a significant longer time in SCT preoperative. In patients with complications the postoperative exercise capacity was reduced by 4%. [185,191]

Dong et al. showed that a SCT could predict postoperative complications in patients with non-small lung cancer. They used a SCT-protocol, covering a maximum height of 18,4m. Desaturation in patients was associated with prognosis. [192]

Cardiological and other patient groups of internal medicine

Devendra et al. used a SCT to provoke exercise oxygen desaturation in patients with a persistent foramen ovale. 50 patients were examined. The protocol included climbing and descending 4 flights of stairs. During this procedure oxygen saturation was measured. Provoked exercise desaturation (PED) was defined as a desaturation of at least 8% and a saturation <90%. 17patients had a PED. 13 of them underwent PFO-disclosure. 10 were followed up. The desaturation improved after closure by a mean of 10%. [171]

Njoeten et al. assessed patients with long Covid. They used a SCT protocol, covering 18 steps, which had to be climbed 3 times up and down as fast as possible. Patients with a normal exercise capacity in CPET were significantly faster as those with reduced exercise capacity. [193]

Hellberg et al. showed that a decline in glomerular filtration rate is associated with a reduced endurance, strength and other symptoms. Endureance was assessed, using a SCT.

The SCT covered a total of 12 flights. [194]

Patients requiring general surgery

Servio et al. used the SCT to investigate CRF in patients before and after laparoscoptic Nissen-fundiplicatio. The working group used the SCT protocol of Cataneo et al. It covered a total height of 12,24m, which had to be climbed as fast as possible. Time was recorded and power calculated. Several measurements on different times were collected. They could show that the patients regained their preoperative results shortly (at the 5th postoperative day) after operation. [195]

Arruda et al. assessed cardiopulmonary postoperative complications in comparison between upper abdominal and thoracic surgery, using a SCT. [196]

Khenaifes et al. evaluated CRF in patients before and after cholecystectomy, using a SCT. For the SCT a protocol according to Cataneo et al. was used. A total height of 12,24 meters was covered. They could show a rapid recovery of CRF after surgery. [197]

Cataneo et al. used a standardized protocol in their studies to establish a submaximal exercise test in hospital settings where CPET is not available, to evaluate if the cardiorespiratory system of an individual has the capacity to undergo surgery. They used a SCT protocol, covering 6 flights (12,16m), measured time and calculated the individuals work to climb the stairs. To calculate the work needed to climb the stairs, the body mass, the covered height and gravity was multiplied. The calculated work was divided by the time needed to climb, to get the stair climbing power in Watt. The results were compared to VO2max during CPET. They could show a significant correlation between VO2max and SCT as well as SCT power. As a conclusion they stated that the SCT is a simple cost effective and widely available test to assess an individual's cardiorespiratory capacity, as patients with an impaired cardiac or pulmonary function have difficulty climbing stairs. The working group stated that a SCT should cover a height of at least 12m to get convincing results. [185,198]

Normal-weight and overweight healthy study participants

Coll et al. used a modified Chester step test in healthy adults. They used a 20cm step, which had to be stepped on and off on a standardized cadence, which was increased every 2 min. The test was stopped, either symptom limited, or when the individuals reached a heart rate equal to 80% of their maximum HR (220-age). A modification was added in individuals, who reached a cadence of 35 steps/min without reaching any of the mentioned criteria. They were handed 2kg dumbbells. The test was performed twice, and the results were almost equal in both rounds. They found the SCT a reliable test to assess aerobic capacity. [199].

Hetzler et al. developed a football stair climb protocol, including 20 steps with a total height of 3,12m. As football is described as a highly explosive sport, the group was looking for a test to assess peak anaerobic power. 58 football players were included. They performed 25 trials with 30-40sec rest in between. Time was recorded and power calculated. Power was calculated according to the following formula: Power = body mass (kg) x 9.81 ms^{-2} x vertical distance x $time^{-1}$. The players were divided in 3 groups, according to their position in the game. The skill-group was significantly less powerful. They could show that the test is reliable for measuring peak anaerobic power. To assess the reliability of the test 34 football players repeated the test within a week. [172]

Calavalle et al. used the SCT as a simple method to analyze overall individual physical fitness in firefighters.[200]

Boreham et al. performed a „training program" including stair-climbing in a group of sedentary female students. The effect of this program on CRF was assessed, using a SCT before and after the program. During a 135sec SCT VO2 and HR was measured with a portable spirometry. After the program a reduction in VO2 and HR was measured, which suggested a cardiovascular health benefit. [168]

The working group Lafortuna and Sartorio et al. examined obese individuals with a SCT. In their first study they assessed the anaerobic power output in adult obese individuals (BMI 30-60kg/m2). A modification of the Margaria stair climbing test, covering a flight with 13 steps was used. The individuals were asked to climb at their highest speed possible. With the collected data, they calculated the average mechanical power output: W= (Mb x g x h)/t (Mb=body mass, g=gravity, h=vertical height, t=time). They showed a significant correlation between mechanical power output and BMI. A higher BMI was associated with a higher mechanical power output. The power output also correlated significantly with the amount of fat free mass, whereas men had a higher amount of fat free mass. With aging the fat free mass decreases in both genders. In their second study the group used the same SCT. In this population of obese women, not all were able to perform the test. In this study a <40 BMI had a significant effect on power output, values >40 had not. In the third study severly obese children and adolescents were examined with the same protocol as the obese adults before. They also showed a significant correlation between power output and fat free body mass. Up to the age of 13 they could not detect a significant difference between boys and girls. Due to age a significant increase in power output could be shown. From the age of 13 boys further gained power output, whereas girls started to build a plateau. [106,169,170]

Oesch et al. examined patients with lower back pain. They used a SCT protocol, covering 100 steps. [201]

3.1.3. Other parameters

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Apart from the approaches mentioned above, there are a few trials, which investigated the effect of stair climbing regarding blood sugar [202–205], or cognitive function. [206] Another working group investigated the effect of a musical prompt on the pace of stair climbing. [15] Poppius et al. used a SCT to simulate exercise and evaluated whether doxantrazole can prevent exercise-induced asthma. [207] Aveline et al. assessed pain and recovery after knee arthroplasty. [208]

3.2. SCT-protocols and implementations

In most trials the test was conducted with 10 steps or more. Almost all studies evaluated the ascending as well as the descending. Other studies focused solely on ascending, as for example Lee et al. who used the SCT for evaluating the walking ability of stroke patients. [94]

Step height was mentioned in the majority of the included trials (Tables 1–3). The used stairs varied in step height between 7,8 and 20 cm. (Tables 1–3) Some of the studies specified the total amount of steps to be covered and thus the total vertical height. A trial by Novoa et al. showed an adequate exertion level from 12 meters and more, comparable to an unlimited approach. [209]

Several studies used a variation of the Margaria-SCT protocol, covering a total vertical height of 1,99m. [210] Other groups orientated towards the protocol used by Cataneo et al., covering a total vertical height of 12m. [185]

Various trials used one staircase repetitively and instructed their patients to climb up and down for a certain amount of time. (Tables 1–3) This approach was for instance used by Smeets et al., who investigated the physical capacity of patients with lower back pain. [84]

3.2.1. Measured SCT performance parameters

With a total of 122, most of the included trials used the total time needed to complete the SCT as the only measured parameter.

15 other trials counted the number of steps completed in a fixed time. Some trials calculated the cadence.

Other parameters collected included vital signs, the number of steps climbed and the so-called stair-climbing power (Tables 1–3). Capturing stair-climbing power was mentioned in 41 articles. To calculate the stair-climbing power, the height climbed, the body weight, the acceleration of gravity and the time required to complete the SCT were used in most of the cases. (Tables 1–3) The Cadence of stair-climbing was assessed in 6 trials. Predicted VO2max was calculated in 7 studies. **Physical and neuromuscular function/mobility:**

Table 1. 155 Studies evaluating neuromuscular/physical function.

Author, Study Design, Number of Participants	**Study Background**	**SCT-outcome**	**SCT-technical background**	**SCT-implementation**	**SCT- parameters surveyed**
Skelton DA et al. 1995 CT, n= 40 [124]	Effects of Resistance Training on Strength, Power, and Selected Functional Abilities of Women Aged 75 and Older	functional ability	6 flights 12 steps Flight height: 1,885 m	climb up a staircase as far as possible without stopping at a comfortable pace without using the handrail.	-flights per second -heart rate (mean of the final 15 seconds)

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Schwid SR et al. 1997 CT, n= 10 [91]	Quantitative assessment of sustained= release 4=aminopyridine for symptomatic treatment of multiple sclerosis	motor function	4 steps step height: 15,24 cm	climb four steps of stairs as quickly as possible.	-time to ascend
Sharp SA et al. 1997 CT, n= 15 [99]	Isokinetic Strength Training of the Hemiparetic Knee: Effects on Function and Spasticity	physical function	1 set, 4 stairs, step height: 17,7 cm	climbed up at a comfortable speed, using their normal pattern of foot placement and hand support.	-time to ascend (average of 3trials -calculated cadence (stairs/minute)
Teixeira-Salmela LF et al. 1999 CT, n= 13 [100]	Muscle Strengthening and Physical Conditioning to Reduce Impairment and Disability in Chronic Stroke Survivors	functional performance	5 steps, Step height: 17,7 cm	climb up 5 steps of stairs at a comfortable speed, using their usual patterns of foot placement and hand support. Two trials were completed.	-average time and cadence (stairs per minute)
Kovacs I et al. 2001 CT, n=58 [53]	The therapeutic effects of Cserkeszo˙lo¨ thermal water in osteoarthritis of the knee: a double blind, controlled, follow-up study	physical function	20 steps	ascend and then to descend 20 steps	-time
Sartorio A et al. 2001 CT, n=230 [106]	Changes in motor control and muscle performance after a short-term body mass reduction program in obese subjects	motor control maximal lower limb muscle power	13 steps Step height: 15.3 cm total height: 1.99 m	climb up ordinary stairs at the highest possible speed. Instructer classified the performance	-time -calculated power output

Rutkove SB et al. 2002 RCT, n= 16 [211]	A pilot randomized trial of oxandrolone in inclusion body myositis	physical function	steps unlimited	had to climb as many stairs as possible in 15 seconds.	-number of steps climbed in 15 seconds (best out of two)
Hiroyuki S et al. 2003 CT, n= 34 [125]	Specific effects of balance and gait exercises on physical function among the frail elderly	walking assessment	5 steps step height: 15 cm	climb and descend 5 steps of stairs as fast as possible.	-total time
Katz-Leurer M et al. 2003 RCT, n= 92 [93]	The Influence of Early Aerobic Training on the Functional Capacity in Patients With Cerebrovascular Accident at the Subacute Stage	functional walking	steps unlimited	climb as many stairs as possible at a comfortable speed. Any assisted device was allowed. The test ended when the patient felt fatigue.	-number of stairs climbed
Ljungquist T et al. 2003 CT, n= 186 [83]	Physical performance tests for people with spinal pain—sensitivity to change	physical performance	1 flight, different heights	ascend and descend 1 flight of stairs at a self-selected speed.	-total time
Bonan IV et al. 2004 RCT, n= 20 [101]	Reliance on Visual Information After Stroke. Part II: Effectiveness of a Balance Rehabilitation Program With Visual Cue Deprivation After Stroke	gait	1 set 10 steps	ascend and descend a set of 10 stairs.	-total time
Grant S et al. 2004 CT n= 26 [107]	The effects of a 12-week group exercise programme on physiological and	physical performance	12 steps, step height: 16 cm	climb up 12 stairs, turn on the landing and descend as fast as possible	-time to ascend -time to descend -total time

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	psychological variables and function in overweight women			without using the handrail.	
Kraemer WJ et al. 2004 CT, n=40 [54]	Effect of a Cetylated Fatty Acid Topical Cream on Functional Mobility and Quality of Life of Patients with Osteoarthritis	functional Mobility	1 flight 11 steps Step height: 13,5 cm	ascend and descend a flight of eleven steps as quickly as possible. 3 to 5 trials were performed, the best times were recorded. Use of the handrails was allowed; 2 members of the research staff accompanied the patient to assure maximal safety.	-total time -time to ascend -time to descend
Mengshoel AM et al. 2004 CT, n=31+26 [86]	Associations between walking time, quadriceps muscle strength and cardiovascular capacity in patients with rheumatoid arthritis and ankylosing spondylitis	physical function	22 steps step height 20 cm	walk as rapidly as possible without running up and down a staircase without a railing.	-time
Molsted S et al. 2004 CT, n= 33 [157]	Five Months of Physical Exercise in Hemodialysis Patients: Effects on Aerobic Capacity, Physical Function and Self-Rated Health	physical function	2 flights	ascend and descend two flights of stairs as quickly as possible for 2 minutes.	-number of steps (ascending and descending)

Seynnes O et al. 2004 CT, n= 22 [126]	Physiological and Functional Responses to Low-Moderate Versus High-Intensity Progressive Resistance Training in Frail Elders	functional limitation	4 steps, Step height: 0,15 m Step length: 0.30 m	climb 4 risers of stairs as fast as possible without using a handrail. They did 3 repetitions with 2 minutes break in between.	- Stair-climbing power (force 3distance/time), defined as body weight 3 vertical height climbed/time to ascend steps, expressed in watts
Zaino et al. 2004 CT, n= 47 [104]	Timed Up and Down Stairs Test: Preliminary Reliability and Validity of a New Measure of Functional Mobility	functional mobility musculoskeletal and neuromuscular systems	14-steps step height 19.5-cm	stand 30 cm from the bottom of a flight of stairs "Quickly, but safely go up the stairs, turn around on the top step (landing) and come all the way down until both feet land on the bottom step (landing)." The subjects were allowed to choose any method of traversing the stairs.	-time
Capodaglio D et al. 2005 CT, n=60 [129]	Muscle function and functional ability improves more in community-dwelling older women with a mixed-strength training programme	functional ability	2 flights 12 steps	climb up a staircase as quickly as possible without stopping and without using the handrail as support, to turn around on the top	-time

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				platform and then walk down.	
Galvao DA et al. 2005 RCT, n= 28 [148]	Resistance Exercise Dosage in Older Adults: Single- Versus Multiset Effects on Physical Performance and Body Composition	physical Performance	1 flight, 11 stairs, step heigh: 16 cm	climb a flight of stairs as fast as possible while staying safe and without use of the handrails.	-time to ascend
Laufer Y et al. 2005 CT, n= 103 [55]	Effect of pulsed short-wave diathermy on pain and function of subjects with osteoarthritis of the knee	functional mobiltiy	1 flight 15 stairs step height: 15 cm	First trial: climb 15 steps, using the handrail or a cane was allowed Second trial: descend the same 15 steps of stairs.	-time to ascend -time to descend
Mizner RL et al. 2005 CT, n=40 [18]	Preoperative Quadriceps Strength Predicts Functional Ability One Year After Total Knee Arthroplasty	functional performance	12 steps step height: 18 cm step depth: 28 cm	climb as quickly as they felt safe and comfortable. use of one handrail was allowed if necessary, but encouraged to minimize their use of the handrail. 1practice test 2 tests Assistive devices were allowed only if the subject was unsafe or could not complete	- time (average)

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				the test without the assistance of a cane or walker	
Mizner RL et al. 2005 CT, n=40 [17]	Quadriceps Strength and the Time Course of Functional Recovery After Total Knee Arthroplasty	functional performance	1 flight 12 steps step height: 18cm depth 28 cm	ascend and descend a flight as quickly as it feels safe and comfortable. handrail was allowed if required	-time
Storer TW et al. 2005 CT, n= 12 [158]	Endurance exercise training during haemodialysis improves strength, power, fatigability and physical performance in maintenance haemodialysis patients	physical performance	1 staircase, 4-steps Total height: 0,625 m	ascend a 4-step staircase as fast as possible. One test round, three trials, best time out of the three was taken as stair-climb score.	-time to ascend (stair-climb score) - Power (calculated from subject's body weight, vertical ascent and ascent time)
Eyyigor et al. 2006 CT, n= 20 [150]	Effects of a group-based exercise program on the physical performance, muscle strength and quality of life in older women	Physical performance	10 steps step height 20cm	ascend a staircase and turn on the landing and descend the stairs without stopping and without using the handrail for support.	-time to ascend -time to descend
Galvao DA et al. 2006 CT, n= 10 [122]	Resistance Training and Reduction of Treatment Side Effects in Prostate Cancer Patients	physical performance	1 flight, 13 stairs, step height: 17 cm	climb the flight of stairs as fast as possible while staying safe.	-total time

Henwood TR et al. 2006 RCT, n= 67 [127]	Short-term resistance training and the older adult: the effect of varied programmes for the enhancement of muscle strength and functional performance	functional performance	1 flight 11 steps step height: 16 cm	ascend 11 stairs; without the use of a handrail.	-time to ascend -stairclimbing power (using time to ascend, body weight, gravity, step height, number of steps)
Bar-Haim et al. 2007 CT, n=36 [105]	Prediction of mechanical efficiency from heart rate during stair-climbing in children with cerebral palsy	mechanical efficiency	4 steps step height adjustable 1-17 cm,	walk up and down 4 steps for 4 minutes at a pace of their choice. stopping time and number of ascents recorded.	-number of ascents -stopping time -work - breath-by-breath V˙O2 and HR during exercise
Capodaglio P et al. 2007 CCT, n= 58 [128]	Long-term strength training for community-dwelling people over 75: impact on muscle function, functional ability, and lifestyle	functional abilities	2 flights 12 steps each	climb up as fast as possible without stopping and without using the handrail as support, to turn on the top and walk down again.	-total time
Nyland J et al. 2007 Retro. study n=31 [19]	Self-reported chair-rise ability relates to stair-climbing readiness of total knee arthroplasty patients: A pilot study	functional performance	1 flight 10 steps step height 7-inch (17.8 cm) Step depth 11-inch (27.9 cm)	ascend a flight as quickly as possible without compromising safety. Following a 30-second rest period at the top of the steps, subjects were instructed to descend the steps as	-time

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				quickly as possible without compro-mising safety. Using a handrail was allowed	
Smeets RJEM et al. 2007 RCT, n= 221 [84]	Physical capacity tasks in chronic low back pain	physical capacity	five steps circuit, shaped like an eight	walk a stair up and down for 1 min.	-number of steps climbed
Westlake KP et al. 2007 CT, n=46+24 [130]	Velocity discrimination: Reliability and construct validity in older adults	Physical peformance	13 standard steps	ascend and descend steps using one rail at a "quick, but safe speed". 1-min rest period was allowed at the top and bottom landing. 2 tests	-ascend time -descend time
Bruun-Olsen V et al. 2008 RCT, n= 57 [20]	The immediate and long-term effects of a walking-skill program compared to usual physiotherapy care in patients who have undergone total knee arthroplasty (TKA)	physical function	16 stairs, step height: 16 cm	ascend and descend 16 steps using alternate legs, it was allowed to support themselves by holding onto the rail.	-total time
Dreher M et al. 2008 RCT n= 16 [160]	Exercise in severe COPD: Is walking different from stair-climbing	physical function	44 steps step height: 0.16 m	climb up 44 steps. One group with supplemental oxygen during exercise, one without.	-total time -vitals -blood gas -blood lactate
Galea MP et al. 2008	A Targeted Home- and Center-Based	physical function	1 set, 4 stairs,	climb 4 steps as fast as possible.	-time to ascend

RCT, n= 23 [43]	Exercise Program for People After Total Hip Replacement		step height: 17,5 cm step depth: 29,8 cm adjustable rail	Using the handrail was allowed, without pulling themselves up. Patients did one test trial and completed 2 trials.	-lower-limb power (using weight, height of stairs and time to calculate)
Knapp PE et al. 2008 RCT, n= 61 [116]	Effects of a supraphysiologica l dose of testosterone on physical function, muscle performance, mood, and fatigue in men with HIV-associated weight loss	physical performance	12 steps, 4 middle steps recorded (0,66m height)	ascend 12 steps as rapidly as possible. ascent time recorded over the middle four steps (0.66 m). Handrail holding was allowed for balance.	-ascent time over the middle four steps -stairclimbing power (the product of body mass, total step rise, and the acceleration of gravity all divided by time to traverse the middle four steps)
Kortebein P et al. 2008 CT, n=11 [131]	Functional Impact of 10 Days of Bed Rest in Healthy Older Adults	lower extremity strength and power	stairs	climb stairs as fast as comfortably possible with one hand near, but not on, the handrail.	-stair ascent power participant's weight (N) and the time in seconds to ascend 10 steps (Power 1⁄4 (Distance/Time) 3 Weight)
Lee MJ et al. 2008 RCT, n= 52 [94]	Comparison of Effect of Aerobic Cycle Training and Progressive Resistance Training on Walking Ability After Stroke	walking ability	10 steps	ascend a standardized flight of 10 stairs as quickly and safely as possible, using a handrail for	-time to ascend - Stair climb power (calculated from the time taken to ascend the stairs, the known vertical height, and body mass)

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				support was allowed.	
Schmitt LC et al. 2008 CT n=52 [56]	Instability, Laxity, and Physical Function in Patients With Medial Knee Osteoarthritis	physical function	12 stairs step height: 18 cm	ascend and descend a set of 12 stairs as quickly as they felt safe and comfortable. They were encouraged not to use the handrail, but were not prohibited from doing so for safety.	-time
Storer TW et al. 2008 RCT n=44 [152]	Changes in Muscle Mass, Muscle Strength, and Power, but not Physical Function are Related to Testosterone Dose in Healthy Older Men	physical function	SCT 1: 4 steps, total height: 0,66 m SCT 2: 12 steps, total recorded height: 0,69 m	SCT 1: climb up 4 steps of stairs as fast as possible without using the handrail. SCT 2: climb up 12 steps of stairs, but only from step 4-8 the time was recorded.	-time to ascend 4 steps of stairs -stair climbing power (fastest time achieved, subjects' body weight, total rise height, and the acceleration of gravity)
Vogt L et al. 2008 CT, n= 179 [147]	Cognitive status and ambulatory rehabilitation outcome in geriatric patients	ambulatory status	1 flight step height: 19 cm step depth: 28 cm	ascend and descend a flight of steps step by step as fast and comfortably as possible.	-performance (rated by using a 4-point ordinal scale scoring system based on the subject's difficulty in performing the task and the use of the handrail for support and balance)
Bruun-Olsen V et al. 2009 RCT, n= 63	Continuous passive motion as an adjunct to	physical function and mobility	8 steps, step height: 16 cm	walk up and down eight steps, using	-total time

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[212]	active exercises in early rehabilitation following total knee arthroplasty			alternate legs no handrail or use of a walking aid.	
Eyigor S et al. 2009 RCT, n= 40 [149]	A trial of Turkish folklore dance on the physical performance, balance, depression, and quality of life in older women	physical perfomance	10 steps, step height: 20 cm	climb up 10 steps of stairs, turn on the landing and descend, as fast as possible. Using the handrail for support was not allowed.	-total time
Farquhar S et al. 2009 CT, n=183 [22]	The Chitranjan Ranawat Award The Nonoperated Knee Predicts Function 3 Years after Unilateral Total Knee Arthroplasty	physical function	1 flight 12 steps step height 18 cm	ascend and descend a flight as safely and as quickly as possible; use of one handrail is allowed if required. One practice test, two tests used for	-time
Harmer AR et al. 2009 RCT, n=102 [21]	Land-Based Versus Water-Based Rehabilitation Following Total Knee Replacement	functional mobility	18 steps 1 landing in between	ascend 18 stairs as rapidly as possible. Using handrails and walking aids as required was allowed.	-time to ascend -stair climbing power (=calculated by using body mass, total stair height and ascent time)
LeBrasseur KL et al. 2009 RCT, n=252 [132]	Effects of testosterone therapy on muscle performance and physical function in older men with mobility limitations (The TOM Trial):	lower extremity function mobility	12 steps	ascend a flight of stairs as fast as possible and allowed to use the handrail only if needed. using a switch mat timing system	-time

	design and methods			(Lafayette Instrument Company, Lafayette, IN).	
Petterson SC et al. 2009 RCT, n= 200 [23]	Improved Function from Progressive Strengthening Interventions After Total Knee Arthroplasty	functional performance	12 steps step height: 7,9 cm	ascend and descend 12 steps. Two trials were completed.	-average total time of two trials
Pua YH et al. 2009 CT, n=92 [67]	Self-Report and Physical Performance Measures of Physical Function in Hip Osteoarthritis: Relationship to Isometric Quadriceps Torque Development	Physical performance	6 steps step height: 18 cm step depth: 30 cm	climb up and down 6 stairs in their usual manner. Handrails were on the right side of the stairs, and participants held them loosely for safety if necessary.	-time
Yoshida Y et al. 2009 CT, n=12 [24]	Examining outcomes from total knee arthroplasty and the relationship between quadriceps strength and knee function over time	Physical function	1 flight	go up and down a flight of stairs as quickly as an individual feels safe and comfortably refered to literature	-time
Andersson et al. 2010 CT, n= 198 [85]	Performance Tests in People with Chronic Low Back Pain	physical perfomance	5 stairs unlimited	climb up and down 5 stairs for 1 minute. Using the handrail was allowed.	-number of steps climbed in 1min

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Heiberg KE et al. 2010 CT, n=63 [41]	Pain and recovery of physical functioning nine months after total knee arthroplasty	physical function	8 steps step height 16 cm	walking up and down a flight of stairs, using alternate legs, with no support from a rail or walking aid.	-time
Hirota et al. 2010 CT, n = 493 [133]	Association between the Trail Making Test and physical performance in elderly Japanese	movement parameters	4 steps, step height: 10 cm	ascend and descend 4 steps as fast as possible, using the handrail if needed.	-total time
Stevens-Lapsley JE et al. 2010 CT, n=140 [25]	Impact of Body Mass Index on Functional Performance After Total Knee Arthroplasty	functional performance	12 steps step height 20.1 cm	ascend and descend 12 steps	-time
Wetzel JL et al. 2010 CT, n=64 [87]	Six-Minute Walk Test for Persons with Mild or Moderate Disability from Multiple Sclerosis: Performance and Explanatory Factors	functional lower-extremity strength power	4 steps	ascend, turn, and descend, using a handrail as necessary.	-power: calculated using the following equation: (number of steps * step height [m] * body weight) -time
Zeni JA Jr et al. 2010 CT, n=40 [27]	Clinical predictors of elective total joint replacement in persons with end-stage knee osteoarthritis	functional mobility	12 stairs	ascend the steps on the investigators command, turn around and descend the stairs. Light handrail use was permitted for balance.	-time
Zeni Jr JA et al. 2010 CT, n=155	Early Postoperative Measures Predict	functional performance	1 flight 12 steps	ascend and descend a flight of 12	-time

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[26]	1- and 2-Year Outcomes After Unilateral Total Knee Arthroplasty: Importance of Contralateral Limb Strength			steps as quickly as possible in a safe manner. Use of the handrail allowed if needed for balance. 1 test and then 2 timed trials, (average time was recorded).	
Adunsky A et al. 2011 CT, n= 123 [82]	MK-0677 (ibutamoren mesylate) for the treatment of patients recovering from hip fracture	lower extremity power	4 steps	ascend 4 steps of stairs as fast as possible.	-time to ascend -stairclimbing power (=product of patient's weight, gravitational force, and vertical velocity (staircase height/time)
Christiansen CL et al. 2011 CT, n=36+17 [28]	Weight-Bearing Asymmetry During Sit-Stand Transitions Related to Impairment and Functional Mobility After Total Knee Arthroplasty	functional performance	12-steps	ascend, turn around, and descend a flight of stairs. 2 trials. There was a handrail on the staircase, which participants were encouraged to not use during the test.	-time
Sattler F et al. 2011 RCT, n= 112 [120]	Testosterone Threshold Levels and Lean Tissue Mass Targets Needed to Enhance Skeletal	muscle performance and physical function	12 steps	ascend 12 steps of stairs, time to ascend the middle four steps in the 12-	-time to ascend the middle 4 steps in 12-step staircase -stair climbing power

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	Muscle Strength and Function			step staircase was measured. photocells used to measure time for stair climbing power	
Travison TG et al. 2011 RCT, n=165 [121]	Clinical Meaningfulness of the Changes in Muscle Performance and Physical Function Associated with Testosterone Administration in Older Men With Mobility Limitation	physical function	12-step staircase	ascend 12 steps with and without weights equal to 20% of their body weight. Two trials were required.	-time to ascend -stair-climbing power (product of body weight plus weight carried, total stair-rise, divided by ascent time)
Bade MJ et al. 2012 CT, n=118 [46]	Predicting Poor Physical Performance after Total Knee Arthroplasty	functional performance	12 steps steps height 18 cm depth 28 cm	ascend, turn around, and then descend the steps as quickly as possible in a safe manner. Bilateral handrails were available for use if needed, 2tests	-time
Heiberg CE et al. 2012 RCT, n= 68 [16]	Effect of a Walking Skill Training Program in Patients Who Have Undergone Total Hip Arthroplasty	physical functioning	8 steps, step height: 16 cm	ascend and descend 8 steps as fast as possible without running, instructed to use alternate legs, using the stair rail was allowed.	-time to ascend

Hsieh RL et al. 2012 RCT, n= 72 [213]	Short-Term Effects of 890-Nanometer Radiation on Pain, Physical Activity, and Postural Stability in Patients with Knee Osteoarthritis	physical activity	14 steps, step heigh: 18 cm	ascend and descend a flight of stairs as fast as possible.	-total time
van de Port IGL et al. 2012 RCT, n= 250 [103]	Effects of circuit training as alternative to usual physiotherapy after stroke	functional mobility	5 steps chair placed 0,5 meters from the stairs	modified SCT: combination of the timed up and go test before ascending and descending 5 steps of stairs and then sitting down again. The required time from elevating from the chair to sitting again after the stair climb was measured.	-total time
Alfano LN et al. 2013 CT, n=25 [89]	Correlation of knee strength to functional outcomes in Becker muscular dystrophy	functional performance	4 steps step height: 6 inches = 15,24cm	ascend and descend the stairs as quickly and safely as possible. The use of handrails or other compensatory movement patterns was permitted.	-time
Baert IAC et al. 2013 CT, n=87	Weak associations between structural changes on MRI	physical function	5 steps	ascend, turn around and descend	-time

[78]	and symptoms, function and muscle strength in relation to knee osteoarthritis			3 tests, mean value	
Baert IAC et al. 2013 CT, n=45+20 [77]	Proprioceptive accuracy in women with early and established knee osteoarthritis and its relation to functional ability, postural control, and muscle strength	physical function	5 steps step height 15 cm	ascend, turn around, and descend five steps. mean value of 3 trials	-time
Basaria A et al. 2013 RCT, n= 76 [162]	The Safety, Pharmacokinetics, and Effects of LGD-4033, a Novel Nonsteroidal Oral, Selective Androgen Receptor Modulator, in Healthy Young Men	physical performance (in terms of safety, tolerability)	12-steps, step height: 17 cm	ascend 12 steps as fast as possible. One test round, then two trials	-total time (best out of two) - SCT- Power (calculated from the time elapsed, body weight, and vertical distance)
Chalé A et al. 2013 RCT, n= 80 [153]	Efficacy of Whey Protein Supplementation on Resistance Exercise–Induced Changes in Lean Mass, Muscle Strength, and Physical Function in Mobility-Limited Older Adults	physical function	10 steps	ascend a 10-rise set of stairs as fast as possible, without hold on to the railing or use assistive devices. They did two trials; average time was recorded.	-average time to ascend
Chung JY et al. 2013 CT, n= 24 [29]	Is bicompartmental knee arthroplasty more favourable	physical performance	12 steps, step height: 20 cm step depth:	ascend and descend 12 steps as fast as possible while	-total time (average of two trials)

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	to knee muscle strength and physical performance compared to total knee arthroplasty		30 cm	still staying safe. Using the handrail was allowed. Two repetitions.	
van Leeuwen DM et al. 2013 CT, n=22 [30]	Preoperative Strength Training for Elderly Patients Awaiting Total Knee Arthroplasty	physical function	9 steps	ascend, turn around, and descend "walk as quickly and safely" allowed to use the handrail and instructed to	-time
Vincent HK et al. 2013 CT, n =53 [57]	"Functional Pain," Functional Outcomes, and Quality of Life After Hyaluronic Acid Intra-articular Injection for Knee Osteoarthritis	physical function	1 flight, 12 steps	climb up 12 steps as fast as possible. Repeated 3 times, fastest trial time was used for data analysis.	-time to ascend
Akbaba YA et al. 2014 RCT, n=20+20+20 [31]	Intensive supervision of rehabilitation programme improves balance and functionality in the short term after bilateral total knee arthroplasty	physical function	10 steps step height 19 cm depth 27 cm	climb up and down the stairway, as fast as possible	-time
Bieler L et al. 2014 RCT, n= 122 [63]	Intra-rater reliability and agreement of muscle strength, power, and functional performance measures in patients with hip osteoarthritis	functional performance	10 steps, step height: 16,3 cm step depth: 35,8 cm	ascend and descend a flight of 10 steps without using the handrail. The best result of 2 timed trials was used noted.	-total time

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Hsieh RL et al. 2014 CT, n=40 [75]	Immediate and medium-term effects of custom-moulded insoles on pain, physical function, physical activity, and balance control in patients with knee osteoarthritis	physical function	14 steps step height 18 cm	ascend a flight of stairs as quickly as possible.	-time
Judd DL et al. 2014 CT, n=26+18 [151]	Strength and Functional Deficits in Individuals with Hip Osteoarthritis Compared to Healthy, Older Adults	functional performance	12 stairs	climb a flight of 12 stairs, turn around at the top and descend the same flight as quickly and safely as possible. They were permitted to use the handrail for balance but were instructed not to use the handrail to push or pull	-time
Marmon AR et al. 2014 CT, n=24 [47]	Associations between knee extensor power and functional performance in patients after total knee arthroplasty and normal controls without knee pain	Functional performance	12 steps	ascend and descend 12 stairs	-time

Marmon AR et al. 2014 CT, n=84+68 [79]	Perception and Presentation of Function in Patients with Unilateral Versus Bilateral Knee Osteoarthritis	functional ability	12 stairs	ascend and then descend a flight of 12 stairs as quickly and safely as possible. use of the handrail was allowed if necessary.	-time
Tsukagoshi R et al. 2014 RCT, n= 65 [39]	Functional performance of female patients more than 6 months after total hip arthroplasty shows greater improvement with weight-bearing exercise than with non-weight-bearing exercise	functional performance	10 steps step height: 17,5 cm	ascend 10 steps of stairs.	-time to ascend
Winters JD et al. 2014 restro. study, n=35+23 [38]	Preliminary Investigation of Rate of Torque Development Deficits Following Total Knee Arthroplasty	physical function	12 steps height 18 cm depth 28 cm.	ascend, turn around, and then descend the steps as quickly as possible in a safe manner. The handrail was available for use if needed. 2tests	-time
Zeni, Jr. J et al. 2014 CT, n=56 [80]	Relationship between strength, pain, and different measures of functional ability in patients with end-stage hip osteoarthritis	physical function	12 standard steps	ascend and descend 12 standard steps. A handrail is available during testing	-time

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Zhang M et al. 2014 CT, n=72 [159]	Relation Between Anxiety, Depression and Physical Activity and Performance in Maintenance Hemodialysis Patients	physical performance	22 steps	climb the stairs as fast as possible without running, jumping or skipping steps, and were allowed to use the banister for balance if necessary	-time
Altubasi IM et al. 2015 CT, n=21 [134]	Is quadriceps muscle strength a determinant of the physical function of the elderly?	physical function	1 flight 11 steps step height 17 cm	climb up as fast as possible. 1 practice round 2 trials.	-time to ascend
Becker C et al. 2015 CT, n=201 [146]	Myostatin antibody (LY2495655) in older weak fallers: a proof-of-concept	physical performance	4 steps 12 steps step height: 15-18 cm	climb up 4 and 12 steps of stairs while using the handrail.	-time to ascend
Brenneman EC et al. 2015 CT, n=38 [58]	A Yoga Strengthening Program Designed to Minimize the Knee Adduction Moment for Women with Knee Osteoarthritis	mobility	9 steps	ascend and descend a 9-step staircase as fast and safely as possible without running and without skipping stairs. Using the handrail was allowed. Two trials were completed.	-mean time to ascend -mean time to descend
Chikani V et al. 2015 CT, n=13+13 [123]	Impairment of Anaerobic Capacity in Adults With Growth Hormone Deficiency	physical function leg muscle power	4 flights 48 steps step height 17 cm	ascend four flights as fast as possible, one step at a time. 3 tests separated	-time

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				by a rest period of 5 minutes.	
Dias CP et al. 2015 RCT, n= 26 [135]	Effects of eccentric-focused and conventional resistance training on strength and functional capacity of older adults	functional capacity	8 steps step height: 17 cm step length: 31 cm	climb eight steps without using the handrail. Two trials with 3 min of rest between	-fastest performance time
Harries N et al. 2015 CT, n= 43 [102]	A stair-climbing test for measuring mechanical efficiency of ambulation in adults with chronic stroke.	motor performance	4 steps, step height: adjustable 10 to 20 cm	climb up and down the stairs for 5 min, self-pacing their speed, keeping it constant, using the handrail for assistance if needed. They did two repetitions of the test.	-time
Pirotta S et al. 2015 RCT, n= 26 [136]	Effects of vitamin D supplementation on neuroplasticity in older adults	physical function	10 steps, step height: 7,8 cm	ascend 10 steps of stairs as fast as possible without using the handrail or walking aids.	-time to ascend -stair climbing power
Akbaba YA et al. 2016 RCT, n= 60 [31]	Intensive supervision of rehabilitation programme improves balance and functionality in the short term after bilateral total knee arthroplasty	physical functionality	10 steps, step height: 19cm step depth: 27 cm	climb up and down ten steps, as fast as possible. Two trials	-total time (mean value of 2 trials)
Bittel TC et al. 2016	Adipose tissue content, muscle performance and	Physical function	1 flight 10 steps	climbing a flight of stairs with 10 steps	-time -power

CT, n=79 [109]	physical function in obese adults with type 2 diabetes mellitus and peripheral neuropathy				(calculated from the time taken to ascend the stairs, the known vertical height, gravitational force and body mass)
Collado-Mateo D et al. 2016 CT, n = 20 [90]	Performance of women with fibromyalgia in walking up stairs while carrying a load	step-by- step-performance and trunk tilt	10 steps step height: 17 cm depth: 28 cm	climb 10 stairs without carrying a load, rest for 3 min, repeat the test carrying a load of 5 kg in each hand. sensors for motion capture were used.	-kinematic data
Heiberg KE et al. 2016 RCT, n= 60 [42]	Physical Functioning and Prediction of Physical Activity After Total Hip Arthroplasty: Five-Year Follow-up	physical function	8 steps step height: 16 cm	ascend and descend 8 steps as fast as possible without running, allowed to use the handrail, but not a walking aid.	-total time
Hsieh RL et al. 2016 RCT, n=90 [76]	Clinical effects of lateral wedge arch support insoles in knee osteoarthritis	physical activity	1 flight 14 steps step height: 18 cm	ascend and descend 14 steps in the shortest time possible.	-total time
Reddy S et al. 2016 CT, n=264 [161]	Timed Stair Climbing is the Single Strongest Predictor of Perioperative Complications in Patients Undergoing	physical performance	7 steps	walk down and then up one single flight. Vital signs were collected prior to beginning and immediately after	-time

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	Abdominal Surgery			completing the task.	
Bade M et al. 2017 RCT, n=162 [45]	Early High-Intensity Versus Low-Intensity Rehabilitation after Total Knee Arthroplasty	physical function	1 flight, 12 stairs, step height: 17,1 cm	climb up and down 12 flights of stairs	-total time
Baldwin JN et al. 2017 CT, n=1000 [164]	Reference values and factors associated with musculoskeletal symptoms in healthy adolescents and adults	stair-climbing ability	flight of stairs	timed up and Down Stairs Test by Zaino et al	-time
Baldwin JN et al. 2017 CT, n=1000 [163]	Relationship between physical performance and self-reported function in healthy individuals across the lifespan	stair-climbing ability	flight of stairs	Timed up and Down Stairs Test by Zaino et al	-time
Bieler T et al. 2017 RCT, n= 152 [64]	In hip osteoarthritis, Nordic Walking is superior to strength training and home-based exercise for improving function	functional performance	10 steps, step height: 16,3 cm step depth: 35,8 cm	ascend and descend a flight of 10 steps without using the handrail as fast as possible.	-total time (best out of two trials)
Freisinger GM et al. 2017 CT, n=33 [65]	Relationships Between Varus–Valgus Laxity of the Severely Osteoarthritic Knee and Gait,	physical function	12 steps	ascend and descend a staircase as quickly as possible in a safe manner.	-time

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	Instability, Clinical Performance, and Function			Encouraged not to use the handrail unless necessary to complete the test.	
Johnen B et al. 2017 Pilot study, n=45 [137]	Feasibility of a machine vs free weight strength training program and its effects on physical performance in nursing home residents: a pilot study	physical performance	11 steps	climb 11 risers of stairs as fast as possible)	-time
Loyd BJ et al. 2017 retro. study, n=162 [32]	Influence of Hip Abductor Strength on Functional Outcomes Before and After Total Knee Arthroplasty: Post Hoc Analysis of a Randomized Controlled Trial	physical performance	12 steps	ascend and descend a set of 12 steps with or without the use of a handrail for balance. This task was timed and the faster of the 2 trials used for analysis.	-time
Maffiuletti NA et al. 2017 CT, n=40 [110]	Reproducibility of clinician-friendly physical performance measures in individuals with obesity	physical function	13 stairs height 15 cm depth 32 cm	refered to Perron et al. stand up from a chair, walk 3 m, ascend at a comfortable pace, turn around and descend stairs, walk back to the chair, turn and sit down.	-time

Nilsen TS et al. 2017 CT, n=58 [117]	Effects of strength training on body composition, physical functioning, and quality of life in prostate cancer patients during androgen deprivation therapy	physical function	stairs	SCT refered to literature with and without additional 20kg	-time
Romine PE et al. 2017 CT, n=430 [138]	Task-Specific Fatigue Among Older Primary Care Patients	physical function	2 m high flight	climbing a flight of stairs twice, using a handrail and/or cane if needed. 2tests, average used	-time
Sions JM et al. 2017 CT, n=106 [139]	Multifidi Muscle Characteristics and Physical Function among Older Adults with and without Chronic Low Back Pain	physical function	2 steps depth: 28cm, height: 17cm	fast stair descent, "as quickly and as safely as possible". The average of two trials was calculated	-time
Storer TW et al. 2017 RCT, n= 308 [118]	Effects of Testosterone Supplementation for 3 years on Muscle Performance and Physical Function in Older Men	physical function	12 steps	four repetitions of ascending the stairs as fast as possible without running, first two tests unloaded, second two test whilst carrying weights equivalent to 20 % of their body weight.	-time to ascend -stair-climb Power (=product of the total rise of the 12 steps, body weight plus load carried, and acceleration of gravity, all divided by time)

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Suh MJ et al. 2017 CT, n=34 [49]	Effects of Early Combined Eccentric-Concentric Versus Concentric Resistance Training Following Total Knee Arthroplasty	physical function	1 flight 12 steps step height: 17cm step wide: 25 cm	ascend and descend a flight of stairs as fast as possible on the word "go". 5-minute rest interval betweens tests, the best score was recorded	-time
Gagliano-Juca T et al. 2018 RCT, n=99 [119]	Testosterone does not affect agrin cleavage in mobility-limited older men despite improvement in physical function	physical function	12 steps	climb up and down 12 steps of stairs as fast as possible without running while carrying weight equal to 20 % of their body weight.	-total time -stair-climbing power (=product of body weight plus weight carried, total stair-rise, and acceleration of gravity all divided by ascent time)
Mulla DM et al. 2018 RCT, n= 43 [165]	The Effects of Lower Extremity Strengthening Delivered in the Workplace on Physical Function and Work-Related Outcomes Among Desk-Based Workers	mobility	1 flight 11 steps	ascend and descend a flight of stairs with 11 steps as fast as possible without running and without skipping steps. It was permitted to use the handrail. Two trials were completed.	-average time to ascend -average time to descend

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Mustafaoglu R et al. 2018 Pilot study, n=45 [95]	The effects of body weight-supported treadmill training on static and dynamic balance in stroke patients: A pilot, single-blind, randomized trial	physical function	10 steps step height 17 cm	ascending and descending using handrails or assistive devices were allowed, if necessary	-time
Iijima H et al. 2019 CT, n=57 [69]	Stair climbing ability in patients with early knee osteoarthritis: Defining the T clinical hallmarks of early disease	physical function	11 steps step height 17 cm step width 135 cm step tread 29 cm	wearing the standardized shoes with pressure sensor-mounted insoles, descend and ascend the flight	-time -vertical ground reaction force (GRF) was calculated from sensor-mounted shoe data -power of 11-SCT for identifying early knee OA (Kellgren and Lawrence grade 1)
Judd DL et al. 2019 CT, n=79 [52]	Trajectories of functional performance and muscle strength recovery differ after total knee and total hip replacement: A performance-based, longitudinal study.	physical function	12 stairs	ascend and descend 12 stairs	-time
Kim JH et al. 2019 Retro. Study, n=184 [48]	Functional Outcomes After Critical Pathway for Inpatient Rehabilitation of Total Knee Arthroplasty	functional mobility lower extremity muscles forces	1 flight 12 steps step height: 17 cm step wide: 25 cm	ascend and descend a flight of stairs	-time

Lange-Maia BS et al. 2019 CT, n=829 [140]	Factors influencing longitudinal stair climb performance from midlife to early late life: The Study of Women's Health Across the Nation Chicago and Michigan Sites	physical function	4 standard stairs	ascend and descend the stairs for three consecutive cycles. Using the handrail was allowed if needed.	-time
Moukarzel M et al. 2019 RCT, n=24 [33]	The therapeutic role of motor imagery during the chronic phase after total knee arthroplasty	strength and functional mobility	12 steps step height: 18 cm step depth: 28 cm	ascend and descend 12 steps of stairs as fast as possible. One test round and two trials.	-total time
Nunes GS et al. 2019 CT, n = 32 [88]	People with patellofemoral pain have impaired functional performance, that is correlated to hip muscle capacity	physical function	9 steps step height: 17 cm	ascend and descend 9 steps as fast as possible step by step. Using the handrail was allowed.	-total time
Orange ST et al. 2019 CCT, n= 36 [141]	Short- term training and detraining effects of supervised vs. unsupervised resistance exercise in aging adults	physical performance	1 free standing flight of stairs with 5 steps, step height 20 cm	ascend and descend as quickly possible while staying safe. Using the handrails was permitted if needed.	-total time

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Shimoura K et al. 2019 RCT, n=50 [70]	Immediate Effects of Transcutaneous Electrical Nerve Stimulation on Pain and Physical Performance in Individuals with Preradiographic Knee Osteoarthritis	physical function	11 steps step height: 17 cm	ascend and descend the stairway as fast as possible, started with both feet on the bottom landing and ended in the same position. 2 trials. Using the handrail for support was allowed.	-total time
Sousa-Gonçalves CR et al. 2019 CT, n=8 [111]	Acute Effects of Whole-Body Vibration Alone or in Combination With Maximal Voluntary Contractions on Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Obese Male Adolescents	Musculoskeletal and neuromotor fitness	13 steps step height: 15.3 cm total height: 1.99 m	climb up ordinary stairs at the highest possible speed, according to their capabilities	-time -power: (calculated from the time taken to ascend the stairs, the known vertical height, and body mass)
Suh et al. 2019 CT, n= 195 [74]	Bilateral Quadriceps Muscle Strength and Pain Correlate With Gait Speed and Gait Endurance Early After Unilateral Total Knee Arthroplasty	physical function	1 flight 12 steps step height 17 cm wide: 25 cm	ascend and descend a flight of stairs as quickly as possible. 3trial with five minutes break in between.	-total time (best out of three)
Unhjem R et al. 2019 CT, n=41 [142]	Functional Performance With Age: The Role of Long-Term Strength Training	functional performance	12 steps step height: 17 cm	climbing as fast as possible. Maximum step length was set to 2 stair steps at a time, no handrail	-power (W)

				support was allowed.	
Bade MJ et al. 2010 CCT, n=24 [44]	Outcomes Before and After Total Knee Arthroplasty Compared to Healthy Adults	functional performance	10 steps step height 17.1-cm 12-steps step height 17.1-cm	9 patients were tested on a 10-step staircase, 15 patients and all healthy adults were tested on a 12-step staircase	-time
Daly RM et al. 2020, RCT, n= 216 [154]	Effects of a multinutrient-fortified milk drink combined with exercise on functional performance, muscle strength etc. in middle-aged women	functional muscle power	10 stairs, step height: 17 cm	ascend or descend a flight of 10 stairs as fast as possible without missing a step. Using the handrail if necessary was allowed. They did 1 practice trial and then 3 test trails.	-time to ascend -time to descend -stair climb power on ascend (power (Watts) = 9.81 × body mass (kg) × vertical step height (m) × number of steps / time (s))
Gränicher P et al. 2020 Pilot RCT, n=20 [34]	Preoperative exercise in patients undergoing total knee arthroplasty: a pilot randomized controlled trial	functional performance	8 steps height 16 cm depth 30 cm	ascend and descend a flight at usual walking speed, feeling safe and comfortable. handrail or assistive devices were allowed but not encouraged	-time
Larsen JB et al. 2020 Retro. Study, n=217 [40]	Intensive, personalized multimodal rehabilitation in patients with primary or	lower body strength balance	22 stairs	ascend and descend stairs as quickly and as safely as possible. Use of a handrail and	-time

	revision total knee arthroplasty: a retrospective cohort study			walking aid were permitted if needed.	
Lee SJ et al. 2020 CT, n=84 [51]	Preoperative physical factors that predict stair-climbing ability at one month after total knee arthroplasty	physical function	12 steps step height 17 cm 25 cm wide	ascend or descend the stairs as quickly as possible on the word "go". 3 trial with a 5-min rest interval Using a handrail was allowed	-time
Mustafaoglu R et al. 2020 RCT, n= 51 [96]	Does robot-assisted gait training improve mobility, activities of daily living and quality of life in stroke	mobility	10 steps step height: 18 cm	climb up and down ten steps without skipping any steps, using one foot for each step and descend without stopping. Use of handrail and/or assistive devices was allowed.	-total time
Onodera CMK et al. 2020 N=153 [60]	The importance of objectively measuring functional tests in complement to self-report assessments in patients with knee osteoarthritis	physical function	9 steps and 9 landings step height 18 cm	reach up and down the stairs	-time
Pozzi F et al. 2020	Restoring physical function after knee replacement:	physical function	12 stairs, (15cm rise, 20cm run)	ascend and descend the set of stairs as fast	-total time

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RCT, n=293 [37]	a cross-sectional comparison of progressive strengthening vs standard physical therapy			as possible without skipping steps. Using the handrail was allowed. Time started on command and ended when both feet touched the bottom again.	
Rigamonti AE et al. 2020 CT, n=595 [113]	Impact of a Three-Week in-Hospital Multidisciplinary Body Weight Reduction Program on Body Composition, Muscle Performance and Fatigue in a Pediatric Obese Population with or without Metabolic Syndrome	muscle performance	13 steps step height: 15.3 cm total height: 1.99 m	climb up ordinary stairs at the highest possible speed. 2–3 test trials.	-time
Rigamonti AE et al. 2020 CT, n= 1922 [214]	Effects of a 3-Week In-Hospital Body Weight Reduction Program on Cardiovascular Risk Factors, Muscle Performance, and Fatigue: A Retrospective Study in a Population of Obese Adults with or without	muscle function	13 steps step height 15.3 cm total height 1.99 m	climb up ordinary stairs at the highest possible speed	-time

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	Metabolic Syndrome				
Tamini S et al. 2020 CT, n=16 [112]	Acute Effects of Whole-Body Vibration Exercises at 2 Different Frequencies Versus an Aerobic Exercise on Some Cardiovascular, Neuromotor and Musculoskeletal Parameters in Adult Patients With Obesity	maximal lower limb muscle power motor control	13 steps step height: 15.3 cm total height: 1.99 m	climb up ordinary stairs at their highest speed, in accordance to their capabilities.	-time -power (=product of 1/4patient's weight, gravitational force, and vertical height /time)
Vongsirinavarat M et al. 2020 CT, n=250 [59]	Identification of knee osteoarthritis disability phenotypes regarding activity limitation: a cluster analysis	physical function	Not specified	Timed stair climbing refered to literature	-time
Ahmed Burq HSI et al. 2021, RCT, n= 64 [97]	Effect of whole-body vibration on obstacle clearance and stair negotiation time in chronic stroke patients	mobility function	3 steps step height: 18 cm step depth: 30 cm	ascend and descend 3 steps of stairs in a comfortable speed, accompanied by a therapist. The handrails were used.	-total time
Beckmann M et al. 2021 CT, n=207 [81]	Recovery and prediction of physical function 1 year following hip fracture	physical function	8 steps	ascended and descended 8steps as fast as able without running, using alternate legs and support by stair rail if needed.	-time

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Choi JH et al. 2021 CT, n=149 [36]	Performance-based physical function correlates with walking speed and distance at 3 months post unilateral total knee arthroplasty	physical function	12 steps height 17 cm wide 25 cm	ascend and descend a flight of 12 steps, as fast as possible on the word "go". 3trials, with the 5 min rest in between	-time
Jacksteit R et al. 2021 RCT, n=85 [35]	Low-Load Unilateral and Bilateral Resistance Training to Restore Lower Limb Function in the Early Rehabilitation After Total Knee Arthroplasty: A Randomized Active-Controlled Clinical Trial	physical performance postural control strength of the lower extremities	8 steps step height: 17.5 cm	climb a staircase in a safely and quickly manner using a railing and regular footwear.	-time
Katsoulis K et al. 2021 Retro. study, n=18 [143]	Reliability of Lower Extremity Muscle Power and Functional Performance in Healthy, Older Women	physical function	13 steps step height 18 cm step width 28 cm height 2.34 m	stand at the base of the stairs with feet together and to grab the handrail if necessary during ascent. Upon the instruction "ready, set, go," stair ascent was measured during a "usual" pace (SCUP) and during a "fast" pace (SCFP)	-time -power = ((body mass in kg) × (9.8 m/s2) × (stair height in meter))/(time in seconds)

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				with instructions to ascend "as quickly and as safely as possible."	
Kim BS et al. 2021 CT, n=562 [73]	Associations Between Obesity With Low Muscle Mass and Physical Function in Patients With End-Stage Knee Osteoarthritis	Physical function	1 flight 12 steps step height: 17 cm step length: 25 cm	ascend or descend the stairs as fast as possible upon hearing the word "go". 3 trials, with a 5-minute rest interval between. The fastest time was recorded for each patient	-ascend time -descend time
Khruakhorn S et al. 2021 RCT, n=34 [61]	Effects of hydrotherapy and land-based exercise on mobility and quality of life in patients with knee osteoarthritis: a randomized control trial	physical function	4 steps step width: 26.5 cm step length: 76 cm step height: 15.2 cm	"Walk up – turn back – and go down the stairs as soon as possible but safely" and subsequently started the assessment with the word "Start". 2 trials with a 5-minute rest between were evaluated.	-time
Bayartai ME et al. 2022 CT, n=160 [108]	Changes in the Oswestry Disability Index after a 3-Week In-Patient Multidisciplinary Body Weight Reduction	lower limb muscle power functional ability	13 steps step height: 15.3 cm total height: 1.99 m	climb a staircase at maximum speed. 1-2 test trials	-time

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	Program in Adults with Obesity				
De Zwart AH et al. 2022 CT, n=177 [62]	Association Between Measures of Muscle Strength and Performance of Daily Activities in Patients with Knee Osteoarthritis	functional performance	12 steps	ascending and descending (independently) a staircase as fast as possible without running	-time
Ihl T et al. 2022 RCT, n=1771 [98]	Patient-Centered Outcomes in a Randomized Trial Investigating a Multimodal Prevention Program After Transient Ischemic Attack or Minor Stroke: The INSPiRE-TMS Trial	physical activity	first landing of a stairway	ascend as quickly as possible to the first landing of a stairway. Patients were allowed to use the banisters, if necessary	-power (power=body weight×9.8×height of the staircase/mean time of 2 runs)
Ke D et al. 2022 CT, n = 103 [155]	Study of the Reliability of Field Test Methods for Physical Fitness in Children Aged 2–3 Years	physical fitness coordination ability	5 steps step height 12 cm	climb up the stairs with using both feet alternately and without using the handrail. 2 trials.	-time to ascend (best out of two)
Lee SH et al. 2022 CCT, n=30+30 [72]	Validity of the Osteoarthritis Research Society International (OARSI) recommended performance-based tests of physical function in individuals with symptomatic Kellgren and Lawrence grade	physical function	9 stairs step height 20 cm	ascended and descended as quickly as possible but in a safe manner.	-time

	0–2 knee osteoarthritis				
Lindberg K et al. 2022, RCT, n= 49 [144]	Effectiveness of individualized training based on force– velocity profiling on physical function in older men	physical function	15-steps, Step height: 16 cm	climb up 15 steps of stairs as fast as possible with and without a weight vest of 20 kg.	-time to ascend
Lazzer S et al. 2022 CT, n=139 [114]	Effects of a 3-Week Inpatient Multidisciplinary Body Weight Reduction Program on Body Composition and Physical Capabilities in Adolescents and Adults With Obesity	muscle function	13 steps step height 15.3 cm total height 1.99 m	climb an ordinary stair at the highest possible speed	-time
Petersson N et al. 2022 CT, n=14 [66]	Blood Flow Restricted Walking in Elderly Individuals with Knee Osteoarthritis: A Feasibility Study	Functional performance	11 steps	11step stair climb test refering to another trial	-time
Usubini AG et al. 2022 CT, n=237 [115]	A three-week in-hospital multidisciplinary body weight reduction program exerts beneficial effects on physical and mental health and fatiguability of elderly patients with obesity	muscle function	13 steps step height 15.3 cm total height 1.99 m	climb up ordinary stairs at the highest possible speed	-time -power (kg × 9:81 × 1.99) /s
Carvalho C et al. 2023	Association between ankle	Functional performance	1 flight 11 steps	go up and down a flight	-time

CT, n=39 [68]	torque and performance-based tests, self-reported pain, and physical function in patients with knee osteoarthritis		step height: 17 cm step width: 202 cm step tread: 31 cm	of stairs as quickly and safely as possible.	
Fosstveit SH et al. 2023 CT, n=49 [145]	Associations between Power Training-Induced Changes in Body Composition and Physical Function in Older Men: A Pre-Test–Post-Test Experimental Study	Physical function	15 steps Step height: 16 cm	climb 15 steps as fast as possible. The time was recorded using photocells placed at the bottom and top of the stairs at 85 cm height. Warm-up, 2 unloaded tests and 2 with a 20 kg vest	-time
Jankaew A et al. 2023, RCT, n=47 [71]	The effects of low-level laser therapy on muscle strength and functional outcomes in individuals with knee osteoarthritis	functional performance	13 steps, step height: 18 cm	climb up the stairs, turn around, and climb down as quickly as possible while staying safe.	-total time
Kirschner N et al. 2023 CT, n=24 [50]	Determination of Relationships between Symmetry-Based, Performance-Based, and Functional Outcome Measures in Patients Undergoing Total Hip Arthroplasty	physical performance	14 steps	14-step stair-climbing test Preoperatively with no walking aids. Postoperatively, walking support and the stair railing were used.	-time

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Lanzi S et al. 2023 CT, n=90 [156]	Time-course evolution of functional performance during a 3-month supervised exercise training program in patients with symptomatic peripheral artery disease	functional performance	12 stairs	climb as quickly as possible using a handrail was allowed. 2 tests	-time
Suslov VM et al. 2023 CT, n=28 [92]	Efficacy and safety of hydrokinesitherapy in patients with dystrophinopathy	physical function	4 steps	descent 4-stairs	-time

Table 2. 37 Studies evaluating cardiorespiratory fitness/exercise capacity. **cardiorespiratory fitness, exercise/fitness.**

Author, Study Design, Number of Participants	**Study Background**	**SCT-outcome**	**SCT-technical background**	**SCT-implementation**	**SCT-parameters surveyed**
McKeon JL et al. 1986, CT, n= 18 [173]	The effect of inspiratory resistive training on exercise capacity in optimally treated patients with severe chronic airflow limitation	exercise endurance	steps unlimited	climb a set of stairs at a normal rate. The trial ended when the patient felt breathlessness or weakness.	-number of stairs
Pollock M et al. 1993 CT, n=31 [166]	Estimation of Ventilatory Reserve by Stair Climbing* A Study In Patients With Chronic Airflow Obstruction	CRF	ten flights 18steps step height 18.5 cm width 27cm	climb as far as possible (maximum, ten flights) at a brisk pace without the use of railings and to stop at their symptom limited	-time -number of steps. –expired gas was analysed and estimate VO2 max and minute ventilation

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				maximum or if they developed any unusual symptoms, chest pain, or dizziness. 2nd stair climb after a 2-h resting period to their symptom-limited maximum.	was calculated
Pate P et al. 1996, CT, n= 12 [174]	Preoperative Assessment of the High-Risk Patient for Lung Resection	cardiorespiratory fitness	21 steps step height: 17,5 cm	moderate pace. Exercise to a symptom-limited maximum and to complete the flight of stairs they were on if possible. Using the handrail was not allowed.	-total time -rest- and exercise pulse and oxygen saturation -number of steps climbed -reason for stopping
Boreham C et al. 2000 CT, n = 22 [168]	Training Effects of Accumulated Daily Stair-Climbing Exercise in Previously Sedentary Young Women	cardiorespiratory fitness	unlimited steps	climb up stairs for 135 seconds, wearing a portable, open-circuit spirometry system, with a weight of 2 kg, to measure oxygen uptake and heart rate every 15 seconds.	-heart rate -oxygen uptake -blood lactate
Brunelli A et al. 2001 CT, n= 115 [178]	Stair-Climbing Test to Evaluate Maximum Aerobic Capacity Early After Lung Resection	maximum exercise capacity	16 flights 11 steps step height 0.155 m	climb, at a pace of their own choice, a maximum number of steps and stop only for exhaustion, limiting dyspnea, leg fatigue, or chest pain.	-time - number of steps -vitals -work (height x steps/minute x body weight in kilograms x

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					0.1635) - VO2 max (ml/min) (5.8 x body weight + 151 + 10.1 x work) -maximum oxygen
Brunelli A et al. 2002 CT, n=227 [175]	Predictors of exercise oxygen desaturation following major lung resection	detecting abnormalities in the oxygen transport system desaturation during exercise	16 flights 11 steps each step is 0.155 m in height	climb at a pace of their own choice the maximum number of steps and to stop only for exhaustion, limiting dyspnea, leg fatigue, or chest pain	-vitals HR, SpO2. -work (height x steps/minute x body weight in kilograms x 0.1635) - VO2 max (ml/min) (5.8 x body weight + 151 + 10.1 x work)
Brunelli A et al. 2003 CT, n=229 [177]	Predicted Versus Observed Maximum Oxygen Consumption Early After Lung Resection	aerobic capacity	16 flights 11 steps step height 0.155 m	climb, at a pace of their own choice, the maximum number of steps and to stop only in case of exhaustion, limiting dyspnea, leg fatigue, or chest pain.	-vitals -number of steps -time -work (height x steps/minute x body weight in kilograms x 0.1635) - VO2 max (ml/min) (5.8 x body weight + 151 + 10.1 x work) -maximum oxygen

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Brunelli A et al. 2003 CT, n=109 [176]	Stair Climbing Test as a Predictor of Cardiopulmonary Complications After Pulmonary Lobectomy in the Elderly	aerobic capacity	16 flights 11 steps step height 0.155 m	climb, at a pace of their own choice, the maximum number of steps and to stop only for exhaustion, limiting dyspnea, leg fatigue, or chest pain.	-vitals -number of steps -time -work (height x steps/minute x body weight in kilograms x 0.1635) - VO2 max (ml/min) (5.8 x body weight + 151 + 10.1 x work) -maximum oxygen pulse (VO2 max /max. heart rate)
Lafortuna CL et al. 2004 CT, n=377 [215]	The relationship between body composition and muscle power output in men and women with obesity	Lower limb anaerobic power output	13 steps total vertical distance 1,99m	climb one step at a time, at the highest possible speed	-time -average mechanical power output in W was calculated W=(Mb*g*h)/t
Lafortuna CL et al. 2006 CT, n=463 [169]	The combined effect of adiposity, fat distribution and age on cardiovascular risk factors and motor disability in a cohort of obese women (aged 18-83)	leg power output	13 stairs total height 1,99m	Margaria test for stair-climbing 13stairs as fast as possible one step on a time	-time -power
Sartorio A et al. 2006 CT, n=306 [170]	Age- and gender-related variations of leg power output and body	Lower limb maximal anaerobic power output	not described	Margaria stair climbing test,	-time -power

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	composition in severely obese children and adolescents				
Brunelli A et al. 2007 CT, n=156 [181]	Quality of Life Before and After Major Lung Resection for Lung Cancer: A Prospective Follow-Up Analysis	exercise tolerance/capacity	16 flights 11 steps step height 0.155 m	climb, at a pace of their own choice, the maximum number of steps and to stop only for exhaustion, limiting dyspnea, leg fatigue, or chest pain.	-vitals
Cataneo D C et al. 2007 CT, n = 51 [185]	Accuracy of the stair-climbing test using maximal oxygen uptake as the gold standard	to determine the accuracy of the variables related to the fixed-height stair-climbing test (SCT)	6 flights 12 steps each step height 16,9 cm total height 12, 16 m	climb the total of 72 steps as fast as possible. They received standardized verbal motivation. The test was only stopped when the Patient experienced fatigue, limiting dyspnea, chest pain, or exhaustion.	-time to ascend -work (using patient weight is acceleration due to gravity and the height of the staircase) -power (work divided by time to ascend)
Brunelli A et al. 2008 CT, n=640 [180]	Performance at Symptom-Limited Stair-Climbing Test is Associated With Increased Cardiopulmonary Complications, Mortality, and Costs After Major Lung Resection	exercise tolerance/capacity	16 flights 11 steps step height 0.155 m	climb, at a pace of their own choice, the maximum number of steps and to stop only for exhaustion, limiting dyspnea, leg fatigue, or chest pain.	-vitals -time

Koegelenberg C et al. 2008, CT, n = 44 [183]	Stair Climbing in the Functional Assessment of Lung Resection Candidates	comparing the altitude reached and the speed of ascent during SCT with VO2MAX measured by cycle ergometry regarding exercise capacity	total height of 20 m each flight had 10 steps	climb the stairs as fast as possible as high as possible. The test was completed when the patients either reached the 20 meters or stopped for more than 3 seconds. Stopping or resting during the test was not allowed, using the handrail only for balance.	-resting blood pressure, pulse rate and oxygen sat- uration -Continuous pulse oxymetry during SCT (documented at 12-, 17- and 20-metre elevations) -speed -Blood pressure after the termination of the test
Brunelli A et Al. 2010, CT, n= 109 [182]	Peak Oxygen Consumption Measured during the Stair-Climbing Test in Lung Resection Candidates	to verify an association between the altitude climbed and the V O2 peak measured during the effort	7 flights 22 steps each step height 0.155 m	climb up the stairs at a pace of their choice and to stop as soon as symptoms would appear (exhaustion, limiting dyspnea, leg fatigue or chest pain).	-altitude climbed -speed of ascent -V O2 peak -Blood pressure and respiratory rate before and immediately after completion of the test
Cataneo DC et al. 2010 CT, n=51 [198]	Accuracy of six minute walk test, stair test and spirometry using maximal oxygen uptake as gold standard	cardiorespiratory capacity	6 flights 12 steps each 72 steps total step height 16.9cm total height	climb all the steps in the shortest possible time, patients had to take two or three paces on a flat surface trying to maintain the same speed. Testing was stopped only for fatigue, limiting	-time -work (W) in joules “W= m x g x h” -Stair-climbing power (SCP) in watts “W / SCt”

			12.16m	dyspnea, thoracic pain, or exhaustion.	
Hetzler RK et al. 2010 CT, n=58 [172]	Development of a modified Margaria-Kalamen anaerobic power test for American football athletes.	measure both horizontal and vertical power anaerobic power	20 steps total height 3.12 m	run up an ordinary flight of stairs, 2 steps at a time, as fast as they could, with a 6-m run-up. Electronic timing system was used	-time -power = body mass (kg) 9.81 ms * vertical distance time
Pancieri MV et al. 2010 CT, n=40 [184]	Comparison between actual and predicted postoperative stair-climbing test, walk test and spirometric values in patients undergoing lung resection	exercise capacity	6 flights 12steps (72 steps in total) step height 16.9cm total height 12.16m	climb all the steps in the shortest possible time with verbal encouragement between flights. Testing was stopped only for fatigue, limiting dyspnea, thoracic pain, or exhaustion.	-time
Bernasconi M et al. 2012, CT, n= 56 [186]	Speed of Ascent During Stair Climbing Identifies Operable Lung Resection Candidates	comparison of stair climbing and treadmill exercise testing with respect to an established cut-off value for lung resection	20 steps step height 17,4 cm, total height: 20 meters (approximately 6 floors)	climb the stairs as fast as possible as high as possible. The test was completed when the patients either reached the 20 meters or stopped for more than 3 seconds. Stopping or resting during the test was not allowed, using the handrail only for balance.	-exercise time -height reached -aerobic capacity -peak VO2
Brunelli A et al. 2012 CT, n=296 [179]	Performance at Preoperative Stair-Climbing Test Is Associated With Prognosis After Pulmonary Resection in Stage I Non-Small Cell Lung Cancer	cardiopulmonary fitness	16 flights 11 steps step height 0.155 m	climb, at a pace of their own choice, the maximum number of steps and to stop only for exhaustion, limiting dyspnea, leg fatigue, or chest pain.	-vitals -time

Devendra GP et al. 2012 CT, n=50 [171]	Provoked Exercise Desaturation in Patent Foramen Ovale and Impact of Percutaneous Closure	Desaturation during stair climbing/exercise	4 flights of stairs	Saturations were measured with an OxiMax pulse oximeter in a seated position, standing, while ambulating, and during ascent and decent of 4 flights of stairs. We defined PED as those patients experiencing a sustained arterial desaturation during assessment of at least 8% to a value 90%.	Oxygen saturation
Elbasan B et al. 2012 CT, n=16 [167]	Effects of chest physiotherapy and aerobic exercise training on physical fitness in young children with cystic fibrosis	Power and agility anaerobic power and speed	10 steps step height 15cm	climb the stairs without skipping any steps and using one foot for each step and descend without stopping	-time
Servio TC et al. 2012 CT, n=32 [195]	Study on functional cardiorespiratory changes after laparoscopic Nissen fundoplication1	Strength Correlation to VO2max / CRF	flight with total height 12.24 m	climb all the cases of stairs with 12.24 meters in height as fast as possible. The test was interrupted by fatigue, intense dyspnea, thoracic pain or exhaustion.	-time -estimating power (SCTP) in watts (w) using weight
Arruda KA et al. 2013 CT, n=78 [196]	Surgical risk tests related to cardiopulmonary postoperative complications: comparison between upper abdominal and thoracic surgery	CRF	6 flights 12 steps each height 12.16 m	referd to Cataneo and Cataneo	-time -power

Refai M et al. 2013 CT, n = 283 [187]	Can maximal inspiratory and expiratory pressures during exercise predict complications in patients submitted to major lung resections	respiratory muscle strength (is PImax and PEmax measured before and after SCT	16 flights 11 steps each step height 15,5 cm	climb the maximum number of steps at a pace of their own choice and stop only for exhaustion, limiting dyspnea, leg fatigue or chest pain.	-pulse -capillary oxygen saturation - maximal inspiratory pressure (PImax) -maximal expiratory pressure (PEmax)
Calavalle A et al. 2013 CT, n= 35 [200]	A simple method to analyze overall individual physical fitness in firefighters	physical fitness	69 steps step height: 15 cm	climb up and down as fast as possible without running and without holding on to the handrail. They had to take one step at a time and were accompanied by a sports instructor. Wearing their protective firefighting turnout gear and air bottle (all together 20kg additional weight) and partly 30 kg on top to simulate carrying a person.	-heart rate -number of steps climbed
Ito H et al. 2014 Retro. Study, n=65 [188]	Outcomes of Lobectomy in 'Active' Octogenarians with Clinical Stage I Non-Small-Cell Lung Cancer	cardiopulmonary status	5 flights 18 m	climb the stairs at a pace of their own choice; when they stopped, the reason was recorded.	-time -vitals
Khenaifes TEG et al. 2014 CT, n=50 [197]	Cardiorespiratory evaluation in pre and post operative moments of	cardiorespiratory function	Staircase 12.24 m	refered to Cataneo et al.	-time -power -vitals

	laparoscopic cholecystectomy				
Oesch P et al. 2014 CT, n=145+53 [201]	Functional Capacity Evaluation: Performance of Patients with Chronic Non-specific Low Back Pain Without Waddell Signs	functional capacity	100 stair steps	ascend and descend a flight of stairs until 100 stair steps were completed. Holding on to a handrail was allowed.	-time
Dong J et al. 2017 CT, n = 171 [192]	Stair-Climbing Test Predicts Postoperative Cardiopulmonary Complications and Hospital Stay in Patients with Non-Small Cell Lung Cancer	to predict postoperative cardiopulmonary complications in patients with NSCLC	5 floors 20 steps each step height 15,3 cm total height: 18,4 m	climb up 5 floors as fast as possible. The test was completed when they reached the maximum height, or they showed symptoms like severe dyspnea with oxygen desaturation, severe leg fatigue, or chest pain.	-time to ascend -altitude climbed -heart rate and capillary oxygen saturation before the test, at each floor during the test, and after resting for 15 min after the test
Hellberg M et al. 2017 CT, n=101 [194]	Decline in measured glomerular filtration rate is associated with a decrease in endurance, strength, balance and fine motor skills	endurance	12 flights 10 steps step height 16 cm depth 32.5 cm	ascended or descended until fatigue or reaching 12 flights	-number of stairs

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Kubori et al. 2017 CT, n = 14 [189]	Comparison between stair-climbing test and six-minute walk test after lung resection using video-assisted thoracoscopic surgery lobectomy	Comparing 6MWT and SCT regarding exercise capacity	36 flights 20-31 steps per flight step height 18-19 cm	climb the maximum number of steps at a pace of their own choice until experiencing exhaustion, limiting dyspnea, leg fatigue or chest pain. They were accompanied by staff.	-altitude climbed -pulse oximeter measuring during the test -heart rate, blood pressure, and respiratory rate before and after the tests
Nakamura T et al. 2019 CT, n=162 [190]	Desaturation during the stair-climbing test for patients who will undergo pulmonary resection: an indicator of postoperative complications	exercise tolerance	6 flights 24 steps step height 0.185 m (120 steps) total height 22.2 m	climb stairs at their own pace test ended due to fatigue, dyspnea, leg lassitude, chest pain, or other complaints.	-time -vitals -Borg scale -number climbed
Coll F et al. 2020 CT, n = 83 [199]	Modified Chester Step Test in a Healthy Adult Population: Measurement Properties and Development of a Regression Equation to Estimate Test Duration	exercise capacity cardiorespiratory responses	1 step step height 20 cm	step on and of the step at a standardized cadence dictated by an audio signal. The cadence increased during the test. The test ended after 10 minutes or as soon as participants reached a heart rate equal to 80% of their predicted maximum or showed intolerable symptoms of breathlessness or leg fatigue.	-vitals -Borg scale

Ozeki N et al. 2020 CT, n=98 [191]	Factors associated with changes in the 12-m stair-climbing time after lung lobectomy	exercise capacity	6 flights 11 steps 71 steps with a 35° incline step height 17.0 cm total height 12.07 m	climb all the steps at the shortest possible time with verbal stimulation standardized by the protocol. The test was canceled if fatigue, intense dyspnea, chest pain, or exhaustion was observed. The based on the previous study by Cataneo et al.	-time -VO2max ($VO2t = 43.06 - 0.4 \times SCt$)
Njøten KL et al. 2023 CT, n=65 [193]	Relationship between exercise capacity and fatigue, dyspnea, and lung function in non-hospitalized patients with long COVID	exercise capacity	18 steps	ascend and descend three consecutive times as fast as possible, walking or running but were not allowed to skip any steps.	-time

Table 3. 8 Studies evaluating other aspects. others:.

Author, Study Design, Number of Participants	**Study Background**	**SCT-outcome**	**SCT-technical background**	**SCT-implementation**	**SCT-parameters surveyed**
Poppius H et al. 1977 CT, n= 13 [207]	Exercise-induced Asthma and Doxantrazole	to determine if doxantrazole can prevent exercise induced asthma	16 floors of stairs	climb up the stairs in rhythmic pace, given by sounds from a tape recorder. The test ended, when they reached the top of the stairs or when they had to stop because of fatigue or dyspnea.	-pace of climbing -number of flights that induced post-exercise asthma -peak expiratory flow

Aveline C et al. 2014 RCT, n= 69 [208]	Pain and Recovery After Total Knee Arthroplasty-a 12-Month Follow-up	pain after exercise	10 steps step height 15 cm	walk up and down 10 stairs	-pain analogue scale (VAS)
Khan A et al. 2015 CT, n= 17 [15]	Musical stairs: the impact of audio feedback during stair-climbing physical therapies for children	impact of audio feedback on the use of reciprocal steps	1 flight of stairs	climb up and down one flight of stairs for 1-5 minutes, with and without audio feedback.	- number of steps
Honda H et al. 2016 CT, n = 16 [202]	Stair climbing/descending exercise for a short time decreases blood glucose levels after a meal in people with type 2 diabetes	postprandial blood glucose in type 2 diabetes	21-step staircase step height: 17 cm	ascend and descend 21 steps 6 times without a break. For the ascend they were instructed to climb at a pace of 80-110 steps per minute, for the descend they chose their pace freely. The test was conducted at 60 minutes after meal and 120 minutes after meal.	-heart rate during test -Borg scale -glucose, lactate, C peptide, and non-esterified fatty acid
Takaishi T et al. 2017 CT, n= 14 [203]	Stair ascending–descending exercise accelerates the decrease in postprandial hyperglycemia more efficiently than bicycle exercise	effect of Stair climbing–descending exercise on lowering postprandial hyperglycemia	1 flight 21 steps step height 18 cm	8–10 repetitions of walking down and up one flight of stairs at an intensity of high-moderate to low-vigorous intensity	-heart rate -blood glucose
Bartholomae E et al. 2018 CT, n=30 [205]	Reducing Glycemic Indicators with Moderate Intensity Stepping of Varied, Short Durations in People with Pre-Diabetes	Blood sugar reduction	21 steps	ascended and descended a stairwell continuously	OGTT

Moore J et al. 2020 RCT, n=30 [204]	A single one-minute, comfortable paced, stair-climbing bout reduces postprandial glucose following a mixed meal	Metabolism/Blood sugar	21 steps	0, 1, 3, and 10 min SCD bouts performed at self-selected pace stairwell was ascended and descended in a continuous fashion.	Blood sugar
Matsumoto K et al. 2022 RCT, n=22 [206]	The Effect of Brief Stair-Climbing on Divergent and Convergent Thinking	Divergent and convergent thinking	4 flights 21 stairs	walk downstairs and back after approaching	Ability to think

4. Discussion

This overview shows how broadly the SCT can be used. Varying from age 2 to the elderly, healthy or ill. However, in most of these studies, the focus was solely set on the achieved time during SCT, or the number of steps climbed. Therefore, a lot of significant information was not collected.

Even if the maximum oxygen collection during SCT may not always be directly the same as in CPET, a lot of trials could show a significant correlation, depending on the protocol that was used to perform the SCT.

Nevertheless, the information that can be gathered while preforming an SCT are often not used detailed enough.

While almost all the included studies used time as the main recorded parameter, vital signs were not gathered in all trials, although this should be possible in significantly more studies and could provide important additional information regarding the physical condition of the participants without major effort. A lot of important information seems to unremarkably fade away. For instance, a direct comparison of parameters gathered with CPET would be interesting. Brunelli et al. even showed that it is possible to obtain conclusive VO2-peak values during SCT with a portable gas analyzer. They were also able to demonstrate that there is a correlation between the altitude climbed and the VO2-peak recorded, which could also be interesting in terms of using the SCT as a maximal exercise test, for example. [182]

Moreover, it must be mentioned that the design and evaluation of the SCT differs a lot in between the trials. A guiding thread lacks, even as a basic protocol. For example, the number of steps ranges from a minimum of 1 step [199] to an unlimited number or not even a detailed description. Some used 1 flight repetitively, others used an unlimited staircase. The total height was not always entitled. Some used a given time frame and assessed the number of steps climbed, others used an unlimited time, and subjects were asked to climb until reaching fatigue, others used a given staircase or number of steps/flights and assessed the time needed to complete. There is also a wide variation regarding the instruction, some trials allowed the use of a handrail or other walking aids.

The given instructions concerning the use of aids can of course influence the test results. For instance, if mobility is examined with the SCT and the participants are for example stroke patients with gait instability, as conducted by Mustafaoglu et al.[96] it obviously makes a difference whether the participants are allowed to use walking aids or not. Another example is the use of a handrail if leg strength is investigated and, in some studies, e.g. Daly et al. the participants are allowed to support themselves with the handrail, while in others they are not, which again could lead to different results. [154]

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The different numbers of steps used seem to be due to the different research questions and patient groups. For example, Pate et al. used a staircase with 21 steps per flight and unlimited steps taken to evaluate the cardiorespiratory fitness of their patients. [174] They wanted to use the SCT as a maximal exercise test. Whereas in trials, using only a few steps, as is the trials of Bruun-Olsen et al. who evaluated physical function and mobility in patients during early rehabilitation after knee arthroplasty [212], the SCT was used as a submaximal exercise test for most individuals. This difference is also obvious in the different trials, focusing on anaerobic capacity and therefore using the Margaria protocol [210], which only covers 1,99m vertical height in comparison to the trials, focusing on aerobic fitness and aiming on maximum exertion, using the protocol of Cataneo et al. [185]

Furthermore, it is interesting to note that among the studies included, only a limited number have attempted to standardize the SCT or build upon previously collected data. One notable approach within this context is the utilization of stair-climbing power, as described earlier. This is for instance used by Storer et al. and Harmer et al. [21,115,118,170,172,185,195,197,215] It is an important beneficial information gain, as some trials which for example used the SCT to determine the cardiorespiratory fitness of their patients [174] could show a significantly correlation to VO2max in CPET, as it has been shown in studies before. [185]

Considering this correlation, especially SCT power, defined as body weight x total vertical height divided by SCT time could be a crucial information regarding the CRF assessment with a simple SCT and vice versa a huge lack of information when not gathered while performing SCT.

Almost all the included studies recorded the time required to complete the test whereas only a few recorded other parameters such as vital signs or even blood lactate. (Tables 1–3)

In general, there seems to be a lot of potential in performing a SCT. Nevertheless, the approaches should be focused on a standardized protocol to gather as much information as possible with this simple test.

One possible limitation of the SCT is that the patients may need to be accompanied by staff. This could be necessary for safety reasons, as mentioned for instance by Kraemer ete al. [54] but also, for example, to collect additional data during the test. This may make the SCT more staff-intensive. However, compared to other tests such as CPET, it would still probably require less know-how, equipment and preparation time and is therefore easier to include in less time-consuming examinations.

Limitations

This review has limitations. There is only a limited number of trials, using a SCT. The reviewed studies also have limitations, such as small sample sizes, varying levels of evidence, and different approaches regarding protocols and recorded results.

Moreover, the search was conducted by only two researchers; therefore, the false exclusion of articles cannot be fully dismissed. Nevertheless, the methods and results were approved by the other researchers.

5. Conclusions

The significance of CRF as a prognostic indicator for long-term health outcomes cannot be overstated. Despite its pivotal role, a thorough assessment of CRF is not yet part of routine medical evaluations. While established methods like CPET provide comprehensive insights into CRF, their extensive resource requirements limit their widespread application in routine check-ups.

The SCT presents a promising alternative due to its simplicity and resource-efficiency as well as its wide applicability during age groups. However, the diverse unstandardized protocols and the wide distributed applications across various studies underscore the need for standardization in its implementation. With the significant correlations shown between SCT results and established clinical tests, such as spirometry and the 6-minute walking test, the SCT holds potential for assessing CRF and functional exercise capacity in diverse patient groups. However, it would again be necessary to obtain comparative data, for example from healthy test subjects, in order to be able to use this test also in patients and even pediatric patients.

Establishing standardized SCT protocols could pave the way for its integration into routine medical assessments, benefiting both general populations and specific patient cohorts, particularly children and young adults with congenital diseases such as congenital heart disease. Nonetheless, further research with larger sample sizes and consensus on standardized SCT protocols are imperative to solidify its position as a comprehensive assessment tool within the medical field.

6. Future Goal – Standardization

Studying all those different trials, we developed a standardized protocol, covering all important points of the previous trials.

We aimed for an easy exercise test, which can be used as submaximal and/or maximum test as a supplement to CPET. Our protocol therefore covered 4 flights with a total vertical height of 13,14m. As previous trials showed that a total of at least 12meters vertical height was needed to achieve maximum exertion. The test should be conducted at an individual's maximum pace, without the use of a handrail and without taking 2steps or more. At the top of the 4 flights the individual should turn around and climb down the stairs. Vital signs before and after the test should be recorded. The time needed to complete the test was stopped and the SCT power calculated using the following formula: SCT-Index = (body weight × staircase height)/(SCTtime).

Moreover, we compared the results in SCT (SCTtime and SCTpower) with the results in 6MWT (distance) and CPET (VO2max(ml/min); VO2max (ml/min/kg); oxygen pulse). We could show a significant correlation in different study groups as previously described in the studies above.

We assessed the clinical validity of the SCT in healthy adults as well as in obese adults. Furthermore, in healthy children and adolescents as well as children and adolescents with congenital heart disease.

Overall, we could show promising results for the clinical use of the SCT with this standardized protocol in both, healthy and ill patients, as long as they are able to climb stairs. The SCT is an easy tool to assess CRF, either as a tool in preventive medicine or in the assessment of clinical treatment or condition control.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, S.K.D. and N.A.H.; methodology, S.K.D., M.P.M., J.W. and A.L.; software, J.W.; validation, S.K.D., N.A.H.; formal analysis, S.K.D., N.A.H.; investigation, J.W. and S.K.D.; resources, J.W.; data curation, J.W., S.K.D..; writing—original draft preparation, J.W..; writing—review and editing, S.K.D., M.S., N.A.H.; visualization, J.W. and S.K.D.; supervision, N.A.H.; project administration, S.K.D. funding acquisition, S.K.D.; All authors have read and agreed to the published version of the manuscript.".

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Abbreviations

CHD congenital heart disease
CPET cardiopulmonary exercise testing
CT clinical trial
CCT controlled clinical trial
HR heart rate

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6MWT 6-minute walking test
RCT randomized controlled trial
SCT stair climbing test
VO2max max. oxygen consumption/uptake

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