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Strength-endurance tests among long- term hospitalised children

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Silově vytrvalostní testy u dlouhodobě hospitalizovaných dětí

Bakalářská práce

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ABSTRACT

Strength performance tests are widely used to comprehensively assess a patient's actual physical fitness, strength, and ability to perform activities of daily living. Many standardised tests are under favourable conditions applicable due to their simplicity, availability, and time efficiency. However, as the tests are mostly designed for the adult population, the choice of a suitable test for a child patient is significantly narrowed.

The Bachelor thesis focuses on creating a systematic review of the performance of strength-endurance and explosive strength tests aimed at lower extremities among children aged between three and eighteen years. The tests included in the review are only those applicable within predetermined limitations arising from long-term hospitalization (such as space around the bed, lack of equipment and length of a central catheter tubing).

In the theoretical section, eight tests meeting the predetermined conditions are selected from the PubMed database. The section outlines the basic principle of the selected tests and further mentions the situations or test modifications used in the studies included in the search.

In the experimental section, the tests are applied on 10 patients to determine their applicability, and potential limitations. A questionnaire is utilized with responses based on the from the testing outcomes and knowledge from the theoretical section, to compare and evaluate their applicability. Additionally, all pros and cons of the test application are described.

Based on the study, the degree of applicability varies under various conditions. However, the tests evaluated as the most applicable for long-term hospitalized paediatric patient is 30-Second Sit- to-Stand Test (30SST) as strength-endurance test, and the Standing Broad Jump (SBJ) as the explosive strength test. The Short Physical Performance Battery (SPPB), and the Senior Fitness Test (SFT) also appear to be quite usable.

KEYWORDS

Strength-endurance, explosive strength, long-term hospitalised, paediatric, test, applicability

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ABSTRAKT

Silové výkonnostní testy se široce používají ke komplexnímu posouzení pacientovy funkční síly, celkové fyzické zdatnosti a schopnosti vykonávat aktivity denního života. Existuje velké množství standardizovaných testů, které jsou za příznivých podmínek velmi dobře použitelné pro svou jednoduchost, dostupnost a časovou efektivitu. Testy jsou většinově stylizovány pro dospělou populaci, proto je výběr vhodného testu pro dětského pacienta výrazně zúžen.

Bakalářská práce se zabývá rešerší standardizovaných testů a jejich následnou použitelností dětských pacientech od tří do osmnácti let. Jedná se o silově vytrvalostní a silově výbušné testy dolních končetin. Zahrnuty jsou pouze testy proveditelné za určitého předem stanoveného omezení, určeného okolnostmi dlouhodobé hospitalizace (prostor v okolí lůžka, nedostatek specializovaných pomůcek, délka hadičky centrálního žilního vstupu).

V teoretické části je z databáze pubmed vybráno osm testů, které splňují předem stanovené podmínky. Základní princip daných testů je popsán a dále je zmíněno, v jakých situacích a s jakými modifikacemi byly testy použity ve studiích, vybraných v rešerši. V praktické části jsou testy aplikovány na 10 pacientů, je zjišťována jejich použitelnost a případné limity. Pomocí dotazníku, zodpovězeného na základě výsledků a poznatků z teoretické části jsou testy porovnány. A výhody a nevýhody jejich použití jsou popsány.

Na základě studie se ukázalo, že použitelnost testů se výrazně mění ve vztahu k mnohým podmínkám. Nicméně, ze zahrnutých testů jsou vyhodnoceny jako nejvíce aplikovatelné na dlouhodobě hospitalizovaného dětského pacienta: 30SST ze silově vytrvalostních a SBJ z testů pro explozivní sílu. Baterie SPPB a SFT se zdají být také poměrně použitelné.

KLÍČOVÁ SLOVA

Silově vytrvalostní, silově výbušný, dlouhodobě hospitalizovaný, dětský, test, aplikovatelnost

DECLARATION

I declare that I have independently processed the bachelor's thesis under the guidance of Mgr. Prokop Havrda, cited all used literary and professional sources, and adhered to the principles of scientific ethics. Furthermore, I declare that the same work has not been used to obtain any other degree.

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1 INTRODUCTION

Strength performance tests are widely used to comprehensively assess a patient's actual physical fitness, strength, and ability to perform activities of daily living [1]. They offer valuable insights into the patient's current status and the effectiveness of therapy. There is a large number of standardised tests applicable among various populations, which are highly usable under favourable conditions due to their simplicity, availability, and time efficiency. Due to the shortage of tests specifically designed for children, resulting in a lack of standardised outcomes for this population, the thesis gathers tests potentially applicable to children, even though primary focus of the tests is on different populations of patients.

This thesis is dedicated to long-term hospitalized children, considering the unique conditions of the hospital environment and the impact of prolonged treatment. These children often experience reduced strength, aerobic capacity, and mobility due to their treatment regimen and extended hospital stays, which makes many tests inapplicable. Additionally, many tests require a significant amount of space or specialized equipment, further limiting their utility in less-than-ideal conditions. Furthermore, children in a hospital often have central venous catheters, the tubing of which can pose challenges and hinder the effective conduct of certain tests.

The thesis comprises a systematic review aimed at identifying tests primarily used for evaluation of lower extremity strength-endurance and explosive strength, while also considering the limitations of space, equipment, and whether the test is possible and unproblematic for long-term hospitalised children.

In the theoretical section, basic information and rules about each of the resulting tests is provided, followed by a description of which articles used each test, the type of population or disease involved, and any modifications made to the test.

The experimental section documents the performance of the identified tests on oncological patients and evaluates their suitability in a real hospital setting, determining if all predetermined conditions are fulfilled. Subsequently, it assesses the outcomes through a questionnaire consisting of seven questions. In the discussion section, the final set of applicable tests is highlighted.

2 LITERATURE REVIEW

2.1. Methods of research

The aim of the research was to find an answer to a previously established question: *"What are the possibilities of quantitative assessment of strength-endurance and explosive strength performances of the lower limbs in long-term hospitalised children?"*

The research question was based on the PICo model (Patient/ Problem – children population, Intervention – strength – endurance performance tests, explosive strength tests, Context - long-term hospitalisation, spatial limitations, without special equipment)

A systematic literature review was conducted using the scientific database PubMed between years 2013 and 2023. The systematic reviews, meta-analyses and randomised controlled trials were included. As the search terms were used: ("aerobic" OR "strength" OR "power" OR "exercise" OR "endurance") OR ("physical" AND ("therapy" OR "activity" OR "performance" OR "function"))) AND ("test" OR "assessment" OR "evaluation" OR "score" OR "battery") AND ("lower extremity" OR "leg") AND ("oncology" OR "cancer" OR "chemotherapy" OR "survivor" OR "leukaemia" OR "tumor" OR "ALL").

2.1.1. Inclusion criteria

There were pre-defined inclusion criteria based on the established question. Each article must include at least one strength performance test that aims at lower limbs, occupy a maximum of 5 m^2 and demand no special equipment.

A total of 449 articles were identified through the keyword search (conducted on 2. 10. 2023). After removing duplicates and excluding partially accessible articles, 390 remained. Among these, strength performance tests or batteries containing strength performance tests were present in only 164 articles. The small variety of tests prompted the inclusion of explosive-strength tests in the final selection. Additionally, articles with tests primarily used for another outcome but potentially applicable for evaluating a long-term hospitalized paediatric patients were included, due to a limited availability of applicable tests. The concluding collection comprised 84 articles, containing tests, for which neither special equipment nor an area larger that 5 m^2 is required. In total, eight tests or batteries and were included into the research.

Table 1 List of researched tests with their occurrences among reviewed articles

Test	N of articles
30 Seconds Sit to Stand Test	36
5 Times Sit to Stand Test	16
Short Physical Performance Battery	21
Broad Jump Test	3
Countermovement Jump Test	3
Single Leg Hop Test	1
Senior Fitness Battery	3
Single Heel Raise Test	1

Theoretical descriptions were provided for each test or battery, and the application of these assessments in the studies was duly documented.

2.1.2. Exclusion criteria

Firstly, a total of 60 articles was excluded because they did not provide the complete article, making it impossible to obtain sufficient information. Secondly, 226 studies did not include any strength tests. Thirdly, 62 studies that included a strength test were excluded due to predetermined selection conditions of the tests. Additionally, the next 18 studies included the Timed Up and Go Test in their research. Although some sources suggest that this test can measure participant's strength, none of the studies in the systematic review used the test specially as a measure of strength. Instead, it was employed solely for dynamic balance and mobility evaluation.

Table 2 List of excluded tests with their occurrences among reviewed articles

Test	N of articles
Six Minute Walk Test	44
Nine Minute Walk Test	1
Ten Minute Walk Test	2
Two Minute Walk Test	3
Twenty Foot Walk Test	1
Leg Press	13
Shuttle Walk Test	3
Dynamometer	3
Timed Up and Go Test or 3-Meter Timed Up and Go	34

2.2. Sit to Stand Test

The sit-to-stand test primarily aims to evaluate the function of lower extremity muscles. It is frequently used as an alternative to manual muscle testing and other specialized tests. During the test, participants are instructed to transition from a seated to a standing position and back. [2]

Morimoto et al. [3] describe three phases of the sit-to-stand movement: The first phase involves a motion of the torso forward, the second phase occurs when the glutes lose contact with the chair, and the third phase entails the extension of the knees as the participant straightens up.

The equipment for the test is a stopwatch and an armless chair. However, various studies present different numbers of the chair height. Carmeli et al. [4] specify a chair height of 40 cm in contrast to De Buyser et al. [5] working with a 44.5 cm high chair whereas [6] Bailot et al. mention a 46 cm high chair. Ultimately, Bohannon [2] notes that the height is influenced by an individual and emphasizing the importance of maintaining a consistent height when testing individuals repeatedly or when the data is used for comparison purposes.

As a prevention against movement, the chair is placed against a wall. The participant seats in the middle of the chair with straight back, knees shoulder-width apart and heels slightly closer to the wall than knees. To maintain balance, the participant may have one leg slightly in front of the other. Participant holds their arms crossed on their chest. [7]

The measurement outcome is typically expressed as either the total number of repetitions or the number of repetitions completed within a specific time frame. Bohannon [2] mentions that the sureness of the measurement in seconds is more accurate than the count of repetitions. However, he also points out that not every patient may be able to complete predetermined number of repetitions.

Types of the sit-to-stand test according to Bohannon [2]:

- Time to stand up once.
- Time to complete 3 chair stands.
- Time for 5 sit-to-stand.
- Time to complete full 10 stands.
- Number of sit-to-stand cycles in 10 seconds.
- Number of stands completed in 30 seconds.

2.2.1. 30 Seconds Sit-to-Stand Test

2.2.1.1. Principles

The 30 Second Sit-to-Stand Test (30SST) or 30 Seconds Chair Test is used for a measurement of functional lower extremity strength and mobility. It can be performed by various populations, from children to older adults. The assessment must be demonstrated both slowly and quickly at the beginning and the patient must have the opportunity to try the motion twice before starting the measurement. The patient tries to sit down and stand up as many times as possible within thirty seconds. For the attempt to count, there must be a full seat between each stand. The tester counts each complete stand within 30 seconds and excludes any incomplete attempts. The goal for the patient is not to achieve a certain number of repetitions, but to do as many as possible. [7]

2.2.1.2. Application of the 30 Seconds Sit-to-Stand Test

Among all articles in the systematic review, a 30 Second Sit-to-Stand Test was present in 36 academic papers of which 31 focus on an oncologic population and the remaining 5 articles mention various diagnoses such as osteoarthritis, schizophrenia, or sarcopenia.

Breast malignancy patients were present in the examination of six articles. Among these, article authored by Neil-Sztramko et al. [8] specifically explore aerobic capacity in women before, during, or after treatment. In this study the 30SST was chosen due to its reliability and validity, which have been demonstrated by its correlation with the leg press. In the remaining five articles [9-13], authors quantified the level of physical activity among survivors. They evaluate the effect of resistance training, home-based therapy, yoga, or correlation between physical fitness and disability.

In 25 studies [14-38] various malignancies such as ovarian tumour, colorectal tumour, prostate tumour, and others are explored. In most of the articles, the level of physical activity or its improvement is measured following a specific type of training.

In one of the articles Yildiz Kabak et al. [19] examine impairments in physical activity among children with acute lymphoblastic leukaemia (ALL).. The study highlights the side effects of chemotherapy and the disease itself and its serious impact on the physical, functional, and developmental levels of children with ALL. Typical mentioned side effects consist of muscle weakness, deficits in range of motion, sensory and balance problems, as well as fatigue, somatic complications, emotional issues, and many others that can lead to a decreased quality of life. Yildiz Kabak et al. [19] use the 30-second Sit-to-Stand Test and the Time Up and Go -3 meters test to assess the functional capacity and physical performance of the lower limbs. They compare the

results with the normative scores of the 30SST, as described by McKay et al. [39] which indicate: 23 repetitions for healthy children aged 3 to 9 years and 24-25 repetitions for children aged 10 to 19 years.

Another article focusing on children was written by Nielsen et al. [23]. The study centers on problematics of reduced physical function among children aged 6 to 18 years diagnosed with any type of tumor. The article examines the effectiveness of multimodal rehabilitation strategies which aim at improving the quality of life of survivors, as they are more susceptible to experiencing long-term difficulties due to treatment. The authors utilize the 30SST and other physical function tests within 14 days of diagnosis and 3 months after diagnosis ± 14 days. The study notes the differences in the results, that were caused by the impact of the initial phase of the treatment. The 30SST is described to have decreased by 24% after 3 months with a leukaemia diagnosis. Although the study does not provide specific height of the chair used for the test, it mentions a 90°angle of the knees in the sitting position.

2.2.2. 5 Times Sit-to-Stand Test

2.2.2.1. Principles

The five times sit-to-stand test (5XSST) is designed for adults and typically for older adults [40]. The test is typically used to assess lower extremity strength[41]; balance [42]; and fall risks in people with dementia, ictus, vestibular disorders, balance disorders [43]. It also explores the transitional strategy between two positions [44].

The 5XSST rating is determined by measuring the time it takes (rounded to the nearest decimal place in seconds) for a patient to complete five cycles of transitioning from a seated position to a standing position and then returning to a seated position. The patient is asked to start in the sitting position ensuring their back is against the chair and their arms crossed over their chest. The goal for patient is to perform five transitions between sitting and standing position five times as swiftly as possible. [45]

According to Schaubert et al.[46], the 5XSST test has excellent intra-rater reliability and exceptional test-retest reliability in healthy older adults. Its validity of measuring dynamic balance and functional mobility in older adults was also established through to TUG [47].

2.2.2.2. Application of the 5XSST

The utilization of the 5XSST was described in 17 articles. Among these articles, the focus was on malignancies in 9 articles, while the others addressed various circumstances such as sleep, falls, physical function, and other non-tumor-related topics.

Two studies centre on exercise-based therapy for survivors or patients with ongoing malignancy. Dittus et al. [48] direct attention to combined aerobic and resistance training intervention in cancer survivors, while Williams et al. [49] analyse the effect of a prescribed exercise to reduce falls among people living with or who have survived malignancy. Both studies took advantage of the 5XSST to evaluate the effect of their therapy, just as the next two articles [50, 51] zeroing in on breast malignancy survivors. Ochi et al. [50] investigate the effect of home-based high-intensity interval training, while Serra et al. [51] focus on improving physical activity through resistance training.

Alejo et al. [52] test a prehabilitation program and its effect on the physical and mental state of patients, as well as their preparedness for malignancy treatment. To compare participant's fitness, they use, among other measures, the 5XSTT, specifying a 40 cm chair height.

Taaffe et al. [53] focus on patients with prostate carcinoma affected by the consequences of Androgen Deprivation Therapy (ADT). They mention the adverse effects of the therapy including the reduction of muscle and bone mass, muscle strength, physical function, and many others, and its increased risk of comorbidities and an overall worsened quality of life. The mentioned option to prevent the side effects is exercise, specifically resistance training.

Steffens et al. [54] direct attention to the feasibility, reliability, and safety of the remote version of the 5XSST among patients with gastrointestinal cancer. Adult patients undergoing treatment for lower gastrointestinal tumors were included to complete the test both in face-to-face session and remotely. The feasibility of the test was influenced by inadequate space, inappropriate chair height, or internet connectivity. Reliability was measured by comparing the scores of the remote application with those of the face-to-face application. Safety was defined by the number of events that occurred during the tests performance, such as incidents requiring medical intervention and resulting in life-threatening situations or death.

Mac Donald et al. [55] examine the strength of the quadriceps femoris affected by cancer cachexia. They evaluate its strength because, as per Harridge et al. [56], this muscle, along with several other muscle groups, is recognized for its functional significance in everyday movements such as chair rising and may play a role in falls among the elderly. Mac Donald et al. describe the 5XSST test as a complex functional measure of muscle strength and power that also involves coordination of

lower limb and truncal muscles. Pereia et al. [57] also address decreased strength in the quadriceps femoris, focusing on the natural loss of muscle strength in the elderly and its impact on everyday activities. The 5XSST was used to predict functional impairments and the risk of falls.

Morimoto et al. [3] investigate the physical performance, including lower limb as a possible risk factor for falls among patients with chronic heart failure. Hneycutt et al. [58] focus on falls as well, in this case on the fall compensatory mechanisms among patients after stroke. For these studies, standardised tests, including the 5XSST were used.

Two articles [59, 60] focus on the use of tai-chi in older adults. Both studies evaluate tai-chi and its modification as tools to improve cognitive function, fitness, and coordination. They both utilize the 5XSST as a test of lower limb strength for comparison before and after the intervention.

Last three articles cover very distinct topics. Firstly, Seth et al. [61] investigate the occurrence of a donor-site morbidity among patients undergoing reconstruction of head or neck defects using a portion of the vastus lateralis muscle. Secondly, Brown et al. [62] address the importance of the muscle quality index in mortality prediction. Thirdly, Tighe et al. [63] focus on the correlation between multidimensional sleep health and physical function among older adults.

2.3. Short Physical Performance Battery

2.3.1. Principles

The Short Physical Performance Battery (SPPB) is an objective assessment tool that measures balance, lower extremity strength, and overall functional capacity. [64]

It is employed for assessing individuals with conditions such as multiple sclerosis or pulmonary diseases, but its primary application is as a diagnostic tool for geriatric syndromes. [65] To elaborate, the European Working Group on Sarcopenia in Older People [66] recommends the SPPB to evaluate the severity of sarcopenia. Furthermore, the Asian Working Group for Sarcopenia [67] deems it advantageous to use either SPPB, 6-minute walk test or 5XSST as a measurement tools for identifying declines in physical performance.

The tester should have several tools available, including a pencil, a stopwatch, a freely available instructional tool (either in the form of a paper document or a mobile app), a ruler, and a chair. The test scores range from a minimum of 0 to a maximum of 12 points and include three subtests. [68]

The first one is the Repeated Chair Stand Test, also known as the 5XSST, with a detailed description available in a chapter 2.2.1. The scoring of the 5XSST in the SPPB is as follows:

Zero points if the patient doesn't complete the test, help themselves with hands or takes more than 60 seconds.

Final time 16,70 s or more: 1 point
Final time 13,70 s to16,70 s: 2 points
Final time 11,20 s to 13,69 s: 3 points
Final time 11,19 s. or less: 4 points

The second subtest involves three balance positions: the Side-by-side-stand, the Semi-Tandem Stand, and the Tandem Stand. The patient is required to stand unsupported in each position for 10 seconds.[69]

The Side-by-side-stand test and the Semi-Tandem Stand tests score with 1 point if the patient can hold the position for 10 seconds and 0 if not. The Tandem Stand scores 2 points for balancing for 10 seconds or more, 1 point for 3 to 9,99 seconds, and zero for less. Both the Semi-Tandem and Tandem Stand tests rate each foot separately. [69]

The final subtest is the Gait Speed Test. The patient walks three or four meters at their regular pace, and the time taken is then recorded. Two test trials are conducted, and the faster of the two is recorded. [69]

The official rating for 3 – Meter Walk:
Time more than 6.52 s: 1 point
Time 4.66 to 6.52 s: 2 points
Time 3.62 to 4.65 s: 3 points
Time less than 3.62 s: 4 points

When assessing gait speed over a 4-meter distance, the pathway typically consists of a 1-meter zone for acceleration, a central 4-meter "testing" zone which is the part timed with a stopwatch, and a 1-meter zone for deceleration. The central 4-meter testing zone is bounded by a starting line and a finish line that are not visible to the patient. The assessment of gait speed starts when the patient's leading leg crosses the starting line and finishes when the same leg crosses the finish line. [70]

A key criterion for this review is that the test must be conducted within a maximum space of 5 m^2. This necessitates using the 3-meter option for the distance in the SPPB, even though, when the length of the path was in the articles specified, it was mostly 4 meters.

2.3.2. Application of the SPPB

The SPPB was used in 21 articles. Out of these, 9 use or describe the test on oncological patients, while the other 12 studies center on the utilization of the SPPB across diverse situations and populations.

Among the 9 articles, three tackle the case of breast tumors. All three studies investigate the difficulties of daily living affected by treatment among breast malignancy survivors. Firstly, Lee et al. [71] examines the effect of a community-based physical activity in breast malignancy survivors due to their association with a greater risk of falls attributed to lower limb weakness, slower walking speed, balance dysfunction, and reduced muscular endurance. Secondly, Hsieh et al. [72] reviews gait and balance impairments among survivors in comparison to unaffected adults. Thirdly, Winters-Stone et al. [73] compare supervised aerobic training to resistance training and its effect on physical functioning among survivors.

In this systematic review, there are two studies authored by Winters-Stone et al. The focus of the first one is also on daily-life difficulties, falls, and general loss of mobility among survivors. In this study, Winters-Stone et al. do not specify the type of malignancy among the examined population but aim directly at symptoms of chemotherapy-induced peripheral neuropathy [74]. The second study investigates the effect of resistance exercise among prostate tumor patients on ADT. [75] The next study, authored by Inglis et al. [76] focuses on prostate tumor patients on ADT as well. The authors analyse the effect of high-dose vitamin D supplementation on the increase of physical function.

The next authors who used the SPPB were Spychka et al. [77]. In their study, they examine the feasibility of performance-based assessments on neurological tumor survivors. The SPPB was chosen because of its ability to mimic daily tasks, and it only takes between 5-10 minutes to perform the test. Spychka et al. directly describe the test as feasible due to the lack of equipment and the minimal space required.

In other study, authored by Pamoukdjian et al. [78], the authors aim to predict mortality among older tumor patients. The SPPB was used in the study because it turned out to have the best discriminative value for predicting 6month mortality in older oncology patients.

Rosero et al. [79] also employ the SPPB in the study, in this case, to examine the effect of a 10week structured multicomponent exercise program on physical and cognitive functions in older patients with lung tumor undergoing adjuvant therapy or palliative treatment.

Out of the rest 12 studies, which are not focused on tumor patients, seven [80-86] primarily focus on older adults, assessing their fitness level, quality of life, or corelation with mortality.

None of the mentioned studies include paediatric patients, which is understandable given that the battery primarily designed for geriatric patients. However, many of the articles use the battery on survivors affected by previously present tumors and struggling with worsened physical activity levels, a phenomenon that has also been observed among children who have completed treatment for ALL [1].

2.4. Standing Broad Jump Test

2.4.1. Principles

Standing Broad Jump (SBJ) or Standing Long Jump (SLJ) is a field test that evaluates explosive strength of lower extremities or the ability to apply force in a horizontal direction. Primarily employed in sports training, it tests a participant's jumping ability and serves as a tool for monitoring ongoing changes in performance over time. [87]

According to Rahman et al. [87] and their study about reliability and validity of the test “The SBJ test is reliable for assessing lower body muscular strength for both male and female adolescents.”

To execute the test, a hard, flat surface free of obstacles is necessary to ensure accurate measurements and minimal risks. The participant starts from behind the starting line, standing with their feet parallel and shoulder-width apart. The instruction is to jump as far as possible in a horizontal direction. The result is recorded in centimetres. Thomas et al. [88] state that there is no specific restriction on the limb movement, and participants are not limited in the depth of the countermovement of the legs or in the swing of the arms. Their feet are required to land at the same time. Other condition under which Thomas et al. [88] measured the test, was performing of three trials with a five-minute rest between each attempt, whereas Castro-Piñero et al. [89] measured only two trials. Similarity can be found in 10-15 minutes of warm up before the test itself.

2.4.2. Application of the Standing Broad Jump Test

Three studies in the systematic review implemented the Standing Broad Jump to measure the outcome.

The first study evaluated the evidence for impairments of muscle strength and balance in childhood cancer patients and survivors. This systematic review, conducted by Söntgerath et al.[90], specifically mentions that the impairments are often related to deficits in the lower extremities and its

dysfunction during activities of daily living, such as getting up from a chair, walking or simply standing. They revealed that strength and balance are impaired in most patients during treatment for hematologic malignancies and focus on the benefits of implementing screening for these impairments. The article mentions not only the Standing Broad Jump Test but also the Countermovement Jump (CMJ) or a variation of the Sit to Stand Test as well. However, the study doesn't provide a detailed description of tests.

The second study, written by Bolados et al. [91] centred on the muscular strength in the upper and lower limbs of Chilean school children in relation to their self-esteem and the beneficial effect of physical activity on health outcomes. The children underwent measurements of maximal hand grip using a Jamar dynamometer, and a long jump was performed to determine the maximum distance measured in centimetres over two trials. The version of this jump, described by the authors as one with feet together, is more of a modification to the standard Standing Broad Jump Test. The overall strength index was calculated using the results of the two tests.

The third study investigated the impact of the keto diet on weight loss in taekwondo athletes [92] and its impact on the performance-related physical fitness. In the study The SBJ test was used to determine instantaneous reactionary force by measuring distance.

2.5. Countermovement Jump

2.5.1. Principles

The countermovement jump is an evaluation that gauges lower extremity strength while also providing insights into sprinting performance, emphasising explosive and maximal strength, factors that are quantifiable along with jump height. It is a type of vertical jump frequently utilised in sports to evaluate athletic prowess and pinpoint strengths and weaknesses in athletes. [93] For proper execution, appropriate equipment is necessary to measure jump values, including contact plates, accelerometers, or high-speed cameras. [94]

The jump encompasses five phases: Unweighting Phase, Breaking Phase, Propulsion Phase, Flight Phase, and Landing Phase. McLellan et al. [93] also include a Weighing Phase or stance phase, during which the participant is instructed to stand still for approximately one second while their body weight is measured. It is mentioned that the significance of this phase may be less apparent and is frequently overlooked by researchers and practitioners.

The Unweighting Phase initiates the movement, involving the participant transitioning into a countermovement. During this phase, the centre of gravity shifts backward, and the participant

is showing a force lower than body weight because the body is essentially in a state of free fall. **The Breaking Phase** starts as the participant reaches the lowest point, involving the application of force to decelerate and ultimately halt the free fall from the preceding phase. **The Propulsion Phase** starts after a complete stop of the downward movement. The centre of gravity ascends and the extension in the hip, knee and ankle joints is prompted by applied force. This phase is characterised by the positive velocity leading up to take-off. **The Flight Phase** stars with both lower extremities of the participant off the ground. It includes the upward movement and free fall back to the floor. **The Landing Phase** commences with the initial contact of the feet with the ground and the participant endeavours to absorb the impact optimally by flexing the knee joints. [93-95]

To assess the countermovement, jump without the need for specialized equipment, Spanish scientist Carlos Balsalobre-Fernández developed a specific app named My Jump. This application is designed for the analysis of vertical jumps, enabling users to calculate the time (in milliseconds) between the last contact of the feet on the ground and the initial touch of the feet on the ground. Using this information, the app then computes the jump height, strength, speed, and overall performance, along with additional parameters. [94, 96]

There are two options of the test. In the first one, participant swing with their arms helping themselves into the jump and in the second one, arms are held at the hips. The arm swinging can improve the result up to 10%. The result is measured in centimetres. [94]

2.5.2. Application of the Countermovement Jump

Three studies in the systematic review employed CMJ as a measurement method. The initial study, a pilot investigation titled "The Efficacy of Targeted Exercise on Gross Motor and Neuromuscular Performance in Survivors of Childhood Leukemia", written by Marchese et al. [97] discusses the potential short- and long-term effects of chemotherapy agents. The effects may lead to neuromuscular impairments, including decreased neuromuscular activation, delayed initiation of muscle contraction, diminished amplitude of muscle activity, and a decrease in muscle force-generating capacity. In the study, a training program is implemented with the aim of promoting the ability to lead an active lifestyle while reducing the risk of developing obesity, metabolic syndrome, or frailty at an earlier age. The CMJ was measured by the rate of muscle activation, joint torques of the lower limb and jump height from reflective markers placed on the specific points on the body. The test was performed five times before training and five times after completing training. The age range among the tested patients in this study was 6-14.

The second study is a randomized controlled trial, authored by Chmielewski et al. [98], and it compares the immediate effect of low- and high-intensity, plyometric exercises during rehabilitation for twenty-four patients after ACL reconstruction. Two tests were employed for functional performance outcomes: the Single Leg Hop Test and the Countermovement Jump (CMJ). The Single Leg Hop Test is more described in the chapter 2.6.2. Participants conducted three trials before the actual measurement, during which three jumps with maximal effort were executed and the average of the trials was recorded. In their study, Chmielewski et al. utilized Vertec Power Systems to measure reach distance with arms raised overhead. Subsequently, participants performer a squat countermovement, followed by a vertical jump, and landed on both feet.

The third study, authored by Söntgerath et al.[90], was already described in chapter 2.4.2, due to the inclusion of the Standing Broad Jump Test.

2.6. Single Leg Hop Test

2.6.1. Principles

The Single Leg Hop Test (SLHT) serves as a performance measure testing participant‘s balance, coordination, strength, functional mobility and motion control. [99, 100]

The prerequisite for performing a single leg hop successfully is to have the adequate strength in m. quadriceps femoris. Strength deficiency can cause reduced capacity to generate and absorb force during activity. Nevertheless, this type of test also reflects neuromuscular control, power, joint function, range of motion and the participant’s self-esteem and confidence.[101]

There are various types of the test different in the number of jumps from which it flows, that the argument when choosing the test is the space requirement. They are used in knee rehabilitation programs mostly for patients recovering from anterior cruciate ligament injury or reconstruction, certain types of fractures or even ankle sprains [102]. The tests involve a comparison between the affected and unaffected leg.

Hegedus et al. [103] divides hop test in these variants also:

- Single hop test
- Triple hop test
- Crossover hop test
- 6-meter timed hop test
- Crossover hop for distance

- Triple jump
- Single leg vertical jump

RehabMeasure database [99] also includes lateral, medial or side hop.

The articles included into the systematic review solely utilized single hop test, implying that this test is the only one fully described.

The equipment required for the single hop test is a tape measure and a marker. The participant is directed to stand on one leg, jump as far as possible without losing balance upon landing and the distance is then measured in centimetres from the starting line to the heel of the landing leg. [99]

2.6.2. Application of the Single Leg Hop Test

There is only one study in the systematic review that uses the SLHT. It is the randomized controlled trial, authored by Chmielewski et al. [98], which is first mentioned in the chapter 2.5.2. In the study, the SLHT was conducted only after intervention due to concerns about patient knee safety. In contrast, the CMJ was measured both before and after rehabilitation. During the test, patients stood on the designated leg and hopped forward maximally, with the distance of the hop recorded. The initial testing was conducted on the leg that did not undergo surgery.

2.7. Senior Fitness Test

2.7.1. Principles

The Senior Fitness Test (SFT) is a battery designed to assess the functional fitness of individuals, targeting those aged between 60 and 94 years old. The test comprises measurements of strength, aerobic endurance, and mobility, with each assessment grounded in activities related to daily living. It can identify whether an older adult may be threatened by loss of a functional fitness. Originating as a part of the Lifespan Wellness Program at Fullerton University, it was devised by Dr. Roberta Rikli and Dr. Jessie Jones [104] , sometimes it can be known as the Fullerton Functional Test. The particular assessment within the Senior Fitness Test includes the 30-second chair stand test (the number of full stands from a chair completed in 30 seconds), the 30-second arm curl (biceps) test (the number of biceps curls completed in 30 seconds), the 2 min step test in place (the number of full steps completed in 2 minutes), the Chair sit and reach test (measuring the distance between extended fingers and the tip of a toe while sitting at the front of the chair with legs extended), the Back scratch test (evaluating the reach of one hand over the shoulder and the other one up the middle of the back in

a standing position), and the 8-foot up and go test (measuring the time taken to get up from a seated position, walk 2.44 m, turn, walk back to the chair, and return to the seated position. [105, 106]

In the original protocol, a 2-minute step test is employed to assess the aerobic endurance. However, in some studies, including all three studies described below, the 6-minute walk test was utilized instead. The 6MW test is considered more suitable for individuals with higher fitness levels, although it is much more space-consuming compared to the 2-minute step test [107]. Therefore, the 2-minute step test aligns more closely with the predetermined conditions.

These tests were chosen based on their adherence to the inclusion criteria established for the systematic review, with only three of specifically targeting lower extremity strength or endurance.

The 30-second chair stand test assesses lower limb strength. The results can indicate the patient's capacity to perform daily activities without risk of falling [108]. This test mirrors the assessment detailed in Chapter 2.2.1.

The 2-minute step test measures a participant’s aerobic capacity and accesses their functional fitness level. This test can be used to various populations including those with cardiovascular diseases, pulmonary diseases, tumours, individuals experiencing back pain, and those who are generally healthy. To conduct the test, it is essential to identify a measuring point situated midway between the patient's patella and the top of their iliac crest. The test outcome is determined by the number of times a patient's knee reaches this point within a two-minute duration. [109]

The 8foot up and go test is an assessment for measuring agility and dynamic balance. According to Wang et al. [110], this test is described as a modified version of the TUG test, wherein, due to frequent space limitations, the 8UG was shortened from 3 m to 2.44 m (8 feet) and the turning point was altered from a turning line to a cone marker. To complete this test, an area free of obstacles, a chair about 44 cm high, stopwatch, a cone marker and a measuring tape is required. The participant performs two trials and the better one is taken to the nearest 1/10 second. In their study, Cedervall et al.[111] mention the TUG’s capability to detect individuals at high risk for cognitive decline and falls. Unfortunately, there is insufficient evidence, that can confirm or refute the 8UG test’s predictive ability in this regard.

The 30 second arm-curl test evaluates upper extremity strength. The patient sits on a chair and holds a dumbbell weighting 2,3 kg weight for women and 3,6 kg weight for men in one hand, while keeping the other hand close to the body. The patient is instructed to repeatedly flex the elbow with the palm facing up for 30 seconds. [112]

The chair sit and reach test assesses lower extremity flexibility. The patient sits on the edge of a chair with one leg extended and the foot dorsiflexed, while the other leg is bent at the knee. Then, the patient leans forward the extended leg and reaches with their arms towards their toes. The result is measured as the distance between the patient's fingers and toes.

The back scratch test measures overall shoulder range of motion. The patient stands and attempts to touch their fingers behind their back. The result is measured as the distance between the fingers.

2.7.2. Application of the SFT

There are three studies that conform to the conditions of this review and include the senior fitness test. The Effect of a mixed-exercise program on physical capacity and sedentary behaviour in older adults during cancer treatments [113] and Fat–Fit Patterns, Drug Consumption, and Polypharmacy in Older Adults: The EXERNET Multi-Center Study [114] both focus on older adults, the Strength and Endurance Training in Older Women in Relation to ACTN3 R577X and ACE I/D Polymorphisms [115] mentions only older women.

In the first study, Maréchal et al. [113] tested fourteen participants undergoing cancer treatment after 12 weeks of either an exercise or stretching program. To assess physical capacity, the SFT was used five times, and a Global Physical Capacity Score was calculated. Additionally, maximal strength tests, including leg press and hand grip, were conducted.

The second research, authored by Navarrete-Villanueva et al. [114], focuses on the correlation between physical fitness level and the amount of accumulated adipose tissue associated with health outcomes in older adults. The physical fitness measurements included the components of the Senior Fitness Battery. Additionally, the one-leg stance test was used for static balance measurement. All the tests were performer twice, except for the chair-stand test and 6MW test, which were performer only once.

The third study, written by Romero-Blanco et al. [115], analyses the effect of two genetic polymorphisms on physical condition in a sample of active older women after a two-year training period. Adapted tests from the SFT, including The Chair Stand Test, The Arm Curl Test and The 6 – Minute Walk Test, were used.

Similarly, to the case of the SPPB, this test is specifically designed for the geriatric population, so no articles involving the paediatric population were identified. Furthermore, no studies investigating its application in different populations were found. However, the test comprises some

assessments that, when applied individually, are utilized as tests for diverse populations, which can lead to possible applicability.

2.8. Single Leg Heel Raise Test

2.8.1. Principles

The Single Leg Heel Rise Test (HRT) is an assessment to test calf strength endurance, fatigue, function, and performance. The plantar flexors are tested in repetitive concentric-eccentric motion in unipedal stance. Although not specified for a particular population, it is commonly utilized in orthopaedics and sports medicine. During the test, the participant is directed to stand on one leg against a wall, using their fingers for balance support while maintaining a straightened trunk and knees. Then the participant performs as many heel rises as is possible and the result is based on the number of repetitions accomplished. No equipment for this test is needed. [116]

2.8.2. Application of the Heel Raise Test

The systematic review includes only one study that investigates a heel raise test, examining the impact of chemotherapy-induced neuropathy on malignancy survivors. The study integrates both objective measures such as the Demographic and Clinical Characteristics, the Pain questionnaires or the Self-Administered Comorbidity Questionnaire and objective measures including sensation, balance, or strength.

In discussed study, written by Miaskowski, C., et al. [117], the test for lower extremity strength is described as a heel lift test. Participants are instructed to stand on one leg and lift the heel of the other for a maximum of 15 seconds, with each leg tested only once. Participants are allowed to touch the wall for balance [117]. While the study focuses on the assessing the duration of the test, other studies generally describe the outcome as the number of repetitions.

3 EXPERIMENTAL SECTION

To compare the testing process and applicability of the tests, a questionnaire was created by the author of the thesis. It consists of seven questions, three of which focus on the patient's performance of the test, while the remaining four assess the applicability of the test itself. Questions Q1, Q2 and Q3 are assessed individually for each child by the tester, whereas questions Q4, Q5, Q6, Q7 are also considering the theoretical section of the thesis. The questionnaire was designed to facilitate the comparison of tests with each other and to evaluate the level of usability among the tests.

Table 3: Questionnaire

Q1. Is the child capable of performing the test?	completed without difficulty completed with difficulty unable to complete
Q2. Is the test feasible in the given space?	hospital room hallway not feasible
Q3. Borg CR10 scale	0-10
Q4. Can the test be truly performed without aids?	YES/NO
Q5. How long does it take to complete the test?	under 1 minute under 5 minutes under 10 minutes
Q6. Is the test primarily assessing strength performance?	YES/NO
Q7. Is the test specifically targeting the pediatric population?	YES/NO

Q1: If a patient suffered from additional health problems that prevented them from perform the test, their result was also marked as "unable to complete".

Q2: In the Q2 not only the room in which the test was performed was evaluated, but also the restriction caused by the catheter tube. The reason for the restriction in feasibility was described separately for each patient.

Q3: The Borg CR10 scale is a category-ratio scale. The CR-10 scale is most effective when assessed using specific bodily sensations such as muscle pain, muscle fatigue, or respiratory responses such as shortness of breath or chest tightness. The grade 0 is rated as "no exertion at all" and grade

10 as “maximal exertion”. [118] The only test not graded on the scale was the balance test from the SPPB due to its focus purely on balance.

Q4: If NO, the required equipment is specified.

Q6: Answers to Q6 are evaluated based on information found and noted in the theoretical section of the thesis.

Q7: YES, if the articles included in this study applied the tests to paediatric patients. None were primarily aimed at the paediatric population.

3.1. Patient I

Patient: J. Š.

Date of birth: 2015

Dg: ALL

30SST

Number of sit-to-stands performed: 20 repetitions

5XSST

Time: 6,05 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 1 point (each side)

3m gait:

1. 3,51 s
2. 2,73 s

Standing broad jump:

Not tested.

CMJ:

Not tested.

Single leg hop test:

Not tested.

SFT:

2 min step test in place:

The patient complained about demandingness of the test but was still able to finish it.

8-foot up and go test – time: 6,30 s

Heel raise test:

Unable to complete.

Table 4: Answers to Q1-Q3 of patient I to questionnaire:

	Q1	**Q2**	**Q3**
30SST	Without difficulties	hospital room	3/10
5XSST	Without difficulties	hospital room	2/10
SPPB **Balance**	With difficulties	hospital room	-
SPPB **3m walk**	Without difficulties	hospital room	2/10
SFT **2m step**	With difficulties	hospital room	5/10
SFT **8-foot up and go**	Without difficulties	hospital room	2/10
SBJ	Unable to complete		
CMJ	Unable to complete		
SLHT	Unable to complete		
HRT	Unable to complete		

The patient had central catheter tubing, which in this case was long enough to safely perform the jumping tests. However, the patient experienced pain in hamstrings while attempting to jump. The heel raise test could not be objectively evaluated, as the patient appeared to lack sufficient strength to elevate his heel adequately and was falling on the other foot.

Figure 1 Patient I performing SPPB

3.2. Patient II

Patient: Š. H.

Date of birth: 2010

Dg: ALL

30SST

Number of sit-to-stands performed: 13 repetitions

5XSST

Time: 8,49 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 2 points (each side)

3m gait: Not tested.

Standing broad jump:

Not tested.

CMJ:

Not evaluated.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: 220 knee raises

8-foot up and go test – not tested.

Heel raise test:

Left leg: 27 raises

Right leg: 22 raises

Table 5: Answers to Q1-Q3 of patient II to questionnaire:

	Q1	Q2	Q3
30SST	Without difficulties	hospital room	2/10
5XSST	Without difficulties	hospital room	2/10
SPPB **Balance**	Without difficulties	hospital room	-
SPPB **3m walk**		Not feasible	
SFT **2m step**	With difficulties	hospital room	4/10
SFT **8-foot up and go**		Not feasible	
SBJ		Not feasible	
CMJ	With difficulties	hospital room	2/10
SLHT		Not feasible	
HRT	With difficulties	hospital room	5/10

The 3m gait test, 8-foot up and go test, SBJ, and SLHT were not evaluated due to the short central catheter tubing, which was less than one meter in length. The CMJ was performed twice by the patient, but the measuring tool (mobile application) did not seem to evaluate the result properly. However, Q1-Q3 could have been answered.

Figure 2 Patient II performing CMJ 1

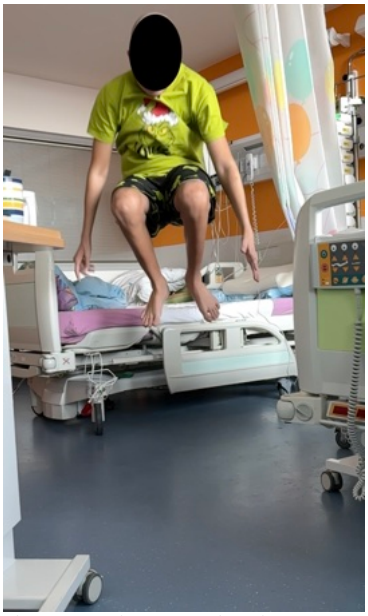

Figure 3 Patient II performing CMJ 2

Figure 4 Patient II performing CMJ 3

3.3. Patient III

Patient: L. G.

Date of birth: 2016

Dg: ALL

30SST

Number of sit-to-stands performed: 35 repetitions

5XSST

Time: 7,31 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 2 points (each side)

3m gait:

2,26 s

2,04 s

Standing broad jump:

Not tested.

CMJ:

Not tested.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: 217 knee raises

8-foot up and go test – time: 4,10 s

Heel raise test:

Unable to complete.

Table 6: Answers to Q1-Q3 of patient III to questionnaire:

	Q1	**Q2**	**Q3**
30SST	Without difficulties	hospital room	2/10
5XSST	Without difficulties	hospital room	2/10
SPPB **Balance**	Without difficulties	hospital room	-
SPPB **3m walk**	Without difficulties	hospital room	0/10
SFT **2m step**	With difficulties	hospital room	3/10
SFT **8-foot up and go**	Without difficulties	hospital room	0/10
SBJ	Unable to complete		
CMJ	Unable to complete		
SLHT	Unable to complete		
HRT	Unable to complete		

The patient could not perform any tests that include jumps because he suffered compression fractures in his vertebrae and was banned from jumping. However, this patient had a catheter tube long enough, about three meters, so if not for the restriction, the jumping tests would have been possible. The HRT was not possible to evaluate objectively as the patient could not elevate his heel high enough and kept falling on the other foot.

Figure 5 Patient III performing SFT 1

Figure 6 Patient III performing SFT 2

3.4. Patient IV

Patient: V. V.

Date of birth: 2010

Dg: ALL

30SST

Number of sit-to-stands performed: 16 repetitions

5XSST

Time: 8,46 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 2 points (each side)

3m gait:

1. 3,63 s
2. 3,15 s

Standing broad jump:

Not tested.

CMJ:

Not evaluated.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: 111 knee raises

8-foot up and go test – time: 8,36 s

Heel raise test:

Not tested.

Table 7: Answers to Q1-Q3 of patient IV to questionnaire:

	Q1	Q2	Q3
30SST	Without difficulties	hospital room	5/10
5XSST	Without difficulties	hospital room	2/10
SPPB **Balance**	Without difficulties	hospital room	-
SPPB **3m walk**	Without difficulties	hospital room	0/10
SFT **2m step**	With difficulties	hospital room	3/10
SFT **8-foot up and go**	Without difficulties	hospital room	0/10
SBJ		Not feasible	
CMJ	With difficulties	hospital room	3/10
SLHT	With difficulties	hospital room	5/10
HRT	Unable to complete		

The patient complained about pain and fatigue in his legs during the testing process. During performance of the 2-minute step test, he experienced pain in his left groin. After a while, the pain subsided, and the test became easier for him. However, the results were affected by the initial pain. The jump tests were not conducted due to the patient's fatigue, pain, and safety concerns related to his short central catheter tube. In contrast to the others, this patient did not appear to struggle with strength-

endurance due to his professional football training. However, the results were affected by the patient's loss of motivation. The SBJ could not be performed due to the length of tubing and danger of its rupture. The HRT was not possible to evaluate objectively. The patient could not elevate his heel high enough to count.

Figure 7 Patient IV performing 30SST 1

Figure 8 Patient IV performing 30SST 2

3.5. Patient V

Patient: D.

Date of birth: 2016

Dg: ALL

30SST

Number of sit-to-stands performed: 13 repetitions

5XSST

Time: 7,27 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 2 points (each side)

3m gait:

1. 2,88 s
2. 1,85s

Standing broad jump:

30 cm

CMJ:

Not evaluated.

Single leg hop test:

Not tested.

SFT:

2 min step test in place:62 knee raises

8-foot up and go test – time: 6,65 s

Heel raise test:

Unable to complete.

Table 8: Answers to Q1-Q3 of patient V to questionnaire:

	Q1	Q2	Q3
30SST	Without difficulties	hospital room	0,5/10
5XSST	Without difficulties	hospital room	0,5/10
SPPB **Balance**	Without difficulties	hospital room	-
SPPB **3m walk**	Without difficulties	hospital room	0/10
SFT **2m step**	With difficulties	hospital room	5/10
SFT **8-foot up and go**	Without difficulties	hospital room	0/10
SBJ	Without difficulties	hospital room	0,5/10
CMJ	Without difficulties	hospital room	1/10
SLHT	Unable to complete		
HRT	Unable to complete		

The patient was capable of performing the standing broad jump test, as his health and the room's space arrangement posed no limitations. However, the result was influenced by his jumping technique. Although the CMJ was attempted, it could not be evaluated due to the mobile app dysfunction. In the SLHT the patient faced challenges with balance and strength preventing an objective evaluation of the test. Similarly, the HRT could not be objectively evaluated due to the patient's inability to elevate his heel sufficiently.

Figure 9 Patient V performing SBJ 1

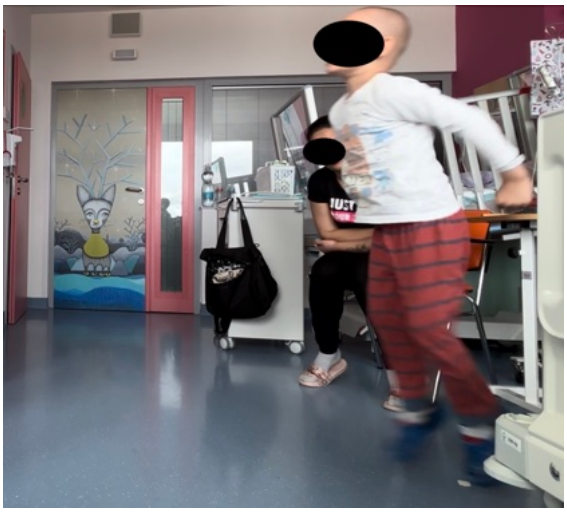

Figure 10 Patient V performing SBJ 2

Figure 11 Patient V performing SBJ 3

3.6. Patient VI

Patient: R. V.

Date of birth: 2018

Dg: ALL

30SST

Number of sit-to-stands performed: 19 repetitions

5XSST

Time: 6,04 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 1 point (each side)

3m gait:

1. 2,82 s
2. 2,91 s

Standing broad jump:

50 cm

CMJ:

Not evaluated.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: not tested.

8-foot up and go test – time: 6,54 s

Heel raise test:

Not tested.

Table 9: Answers to Q1-Q3 of patient VI to questionnaire:

	Q1	**Q2**	**Q3**
30SST	Without difficulties	hospital room	0,5/10
5XSST	Without difficulties	hospital room	0/10
SPPB **Balance**	Without difficulties	hospital room	-
SPPB **3m walk**	Without difficulties	hospital room	0/10
SFT **2m step**	Unable to complete		
SFT **8-foot up and go**	Without difficulties	hospital room	0,5/10
SBJ	With difficulties	hospital room	4/10
CMJ	With difficulties	hospital room	3/10
SLHT	Unable to complete		
HRT	Unable to complete		

The patient successfully completed seven tests, but subsequently felt exhausted and declined to continue.

Figure 12 Patient VI performing SFT 1

Figure 13 Patient VI performing SFT 2

Figure 14 Patient VI performing SFT 3

3.7. Patient VII

Patient: D. B.

Date of birth: 2018

Dg: ALL

30SST

Number of sit-to-stands performed: 15 repetitions

5XSST

Time: 9,55 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 1 point (right foot in the front)

Tandem: 2 points (left foot in the front)

3m gait:

1. 2,18 s
2. 2,58 s

Standing broad jump:

CMJ:

Not evaluated.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: Unable to complete

8-foot up and go test – time: 6,41 s

Heel raise test:

Not tested.

Table 10: Answers to Q1-Q3 of patient VII to questionnaire:

	Q1	**Q2**	**Q3**
30SST	With difficulties	hospital room	4/10
5XSST	With difficulties	hospital room	3/10
SPPB **Balance**	With difficulties	hospital room	-
SPPB **3m walk**	Without difficulties	hospital room	0/10
SFT **2m step**	Unable to complete	hospital room	4/10
SFT **8-foot up and go**	Without difficulties	hospital room	0/10
SBJ	With difficulties	hospital room	4/10
CMJ	With difficulties	hospital room	5/10
SLHT	Unable to complete		
HRT	Unable to complete		

The HRT was not objectively evaluated as the patient could not elevate his heel high enough. Additionally, the patient could not complete the 2-min step test, due to his fatigue.

Figure 15 Patient VII performing SPPB 1

Figure 16 Patient VII performing SPPB 2

Figure 17 Patient VII performing SPPB 3

3.8. Patient VIII

Patient: J.K.

Date of birth: 2017

Dg: ALL

30SST

Number of sit-to-stands performed: 15 repetitions

5XSST

Time: 11,58 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 2 points (each side)

3m gait:

Not tested.

Standing broad jump:

Not tested.

CMJ:

Not evaluated.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: Not tested.

8-foot up and go test – time: Not tested.

Heel raise test:

Not tested.

Table 11: Answers to Q1-Q3 of patient VIII to questionnaire:

	Q1	**Q2**	**Q3**
30SST	Without difficulties	hospital room	2/10
5XSST	Without difficulties	hospital room	0,5/10
SPPB **Balance**	With difficulties	hospital room	-
SPPB **3m walk**		not feasibe	
SFT **2m step**	Unable to complete		
SFT **8-foot up and go**		not feasibe	
SBJ		not feasibe	
CMJ	With difficulties	hospital room	3/10
SLHT		not feasibe	
HRT	Unable to complete		

The patient completed the 30SST, 5XSST, balance test, and CMJ, then he refused to continue, citing fatigue. He mentioned feeling tired and unwilling to proceed. The 3-m gait test, 8-foot up-and- go test, SBJ and SLHT were also not feasible, due to the length of the catheter and space constraints in the room. The SLHT and 2-minute step test were likely impacted by patient's frequent dizziness.

Figure 18 Patient VIII performing 5XSST 1

Figure 19 Patient VIII performing 5XSST 2

3.9. Patient IX

Patient: S. Z.

Date of birth: 2010

Dg: Thrombocytopenia

30SST

Number of sit-to-stands performed: 14 repetitions

5XSST

Time: 6,67 s

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 2 points (each side)

3m gait:

1. 3,05 s
2. 3,32 s

Standing broad jump:

Not tested.

CMJ:

Not tested.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: 108 repetitions

8-foot up and go test – time: 6,81 s

Heel raise test:

Not tested.

Table 12: Answers to Q1-Q3 of patient IX to questionnaire:

	Q1	Q2	Q3
30SST	Without difficulties	hospital room	1/10
5XSST	Without difficulties	hospital room	0,5/10
SPPB **Balance**	Without difficulties	hospital room	0/10
SPPB **3m walk**	Without difficulties	hospital room	0,5/10
SFT **2m step**	Without difficulties	hospital room	2/10
SFT **8-foot up and go**	Without difficulties	hospital room	0,5/10
SBJ	Unable to complete		
CMJ	Unable to complete		
SLHT	Unable to complete		
HRT	Unable to complete		

The patient didn't have central catheter, so there was no restriction in its length or space. The chair was just high enough for her, so tests that include it could have been evaluated properly. The patient struggled with dizziness, so she decided not to perform any jump tests. The HRT was too difficult to perform, the patient could not elevate her heels high enough.

Figure 20 Patient IX performing 30SST 1

Figure 21 Patient IX performing 30SST 2

3.10. Patient X

Patient: Š. K.

Date of birth: 2019

Dg: ALL

30SST

Not tested.

5XSST

Not tested.

SPPB:

Feet together: 1 point

Semi-tandem: 1 point (each side)

Tandem: 1 points (each side)

3m gait:

1. 2,41 s
2. 2,55 s

Standing broad jump:

69 cm

CMJ:

Not evaluated.

Single leg hop test:

Not tested.

SFT:

2 min step test in place: 70 repetitions

8-foot up and go test – time: 3,54 s

Heel raise test:

Not tested.

Table 13: Answers to Q1-Q3 of patient X to questionnaire:

	Q1	Q2	Q3
30SST	Unable to complete		
5XSST	Unable to complete		
SPPB **Balance**	With difficulties	hallway	-
SPPB **3m walk**	Without difficulties	hallway	0/10
SFT **2m step**	With difficulties	hallway	4/10
SFT **8-foot up and go**	With difficulties	hallway	3/10
SBJ	Without difficulties	hallway	0/10
CMJ	With difficulties	hallway	2/10
SLHT	Unable to complete		
HRT	Unable to complete		

In the 5XSST and 30SST, the patient struggled to get up on the chair and expressed fear of injury, resulting in the inability to complete the tests. Remaining tests were conducted in the hallway due to the patient's compliance, not due to space limitations. The CMJ was possible to perform, but it could not be evaluated. In the SLHT, the patient struggled with balance, so he didn't complete the jumps. In the HRT, he was unable to elevate his heel high enough for a valid attempt.

Figure 22 Patient X performing SPPB 1

Figure 23 Patient X performing SPPB 2

4 RESULTS

Ten patients were tested in the experimental section, and the answers to Q1-Q7 were evaluated and expressed using graphs and tables. The graph with question Q1 shows that 30SST, 5XSST and SPPB were mostly unproblematic, and patients were able to perform them easily. The results are favourable for the 8-foot up and go test as well. However, another part of the SFT was mostly hard for the patients to perform.

The most critical were SLHT and HRT, of which the results show minimal applicability. The SLHT was marked three times as not feasible due to space or catheter. However, considering the complete inability of the other patients to perform the test, it is highly unlikely that it would be applicable in these three cases anyway.

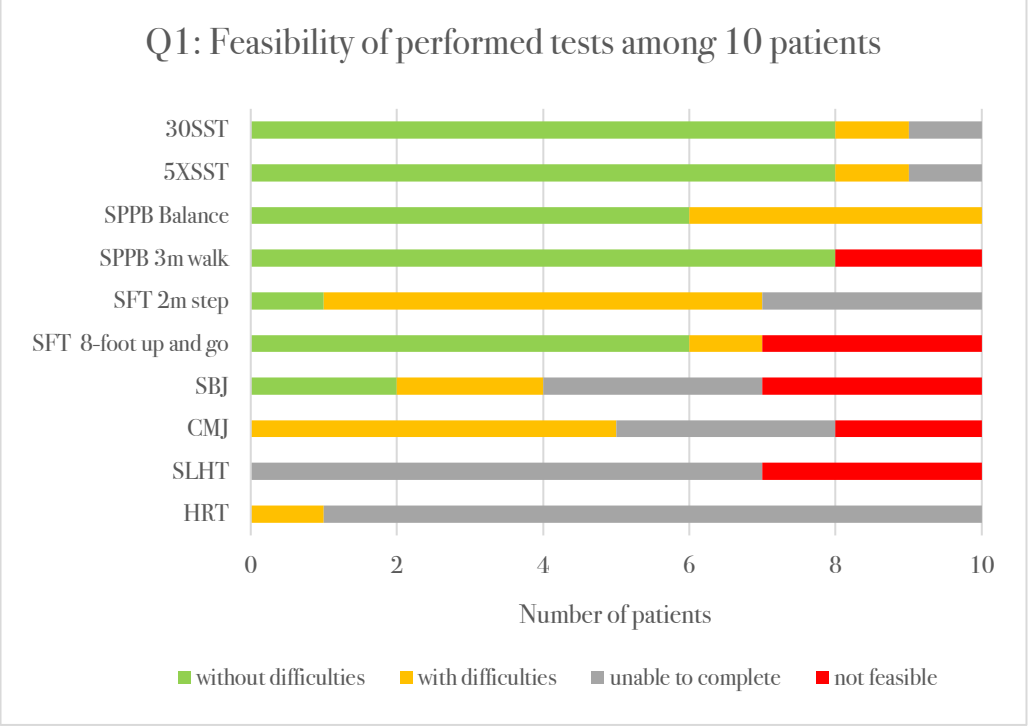

Figure 24 Q1: Feasibility of performed tests among 10 patients

The feasibility of the test within the provided space (Q2) was not assessed with a graph due to very one-sided results. Nine out of ten patients performed all the tests in their hospital rooms. The tests were pre-filtered based on a condition of $5m^2$ in the systematic review, ensuring they did not require excessive space to be limited or rendered infeasible due to the room size. The hospital rooms varied in layout and sizes, which could lead to complications. However, whenever there was an issue with the space in the room, it was always correlated with the insufficient possibility of handling the stand of the catheter or the length of the catheter tube itself. One patient performed all of his tests

outside of the room in the hallway of the hospital ward. This approach required a mobile ward, and a parent of the patient assisted in moving it during the tests that included gait speed, so the tube did not restrict the patient's movement. The decision to conduct the testing outside of the room was solely due to the patient's adherence to the testing, as he experienced emotional discomfort in the room.

The table 14 summarizes the results of question Q3 - the subjective evaluation on a Borg CR10 scale. The graphs describing the frequency of grades for each test individually are further on in the text along with the results of the individual tests.

Table 14 Borg CR 10 Scale – test evaluation summary

	0	**0,5**	**1**	**2**	**3**	**4**	**5**	**7**	**9**	**10**
30SST		4x		2x	1x	1x	1x			
5XSST	1x	3x		4x	1x					
SPPB **3m walk**	6x	1x		1x						
SFT **2m step**				1x	3x	3x	1x			
SFT **8-foot up and go**	4x	2x		1x	1x					
SBJ	1x	1x				2x				
CMJ			1x	2x	2x		1x			
SLHT										
HRT							1x			

The easiest tests to perform were according to the results the 3m walk as part of SPPB and the 8-foot up and go as a part of SFT. The SBJ had the most significant variance in subjective difficulty. Results for tests SLHT and HRT are not validly evaluable due to an insufficient number of successful attempts.

As a part of the evaluation, a table of questions Q4 – Q7 collects the answers based primarily on knowledge from the theoretical section of the thesis. The rest of the evaluation is based on the results of the measurement in the experimental section.

Table 15 answers to Q4-Q7

	Q4	**Q5**	**Q6**	**Q7**
30SST	NO – chair, timer	Under 1 minute	YES	YES
5XSST	NO – chair, timer	Under 1 minute	YES	NO
SPPB	NO – chair, meter, timer, tape	Under 5 minutes	NO – but includes it	NO
SFT	NO – chair, meter, timer, tape	Under 5 minutes	NO – but includes it	NO
SBJ	NO – meter	Under 1 minute	YES	YES
CMJ	NO – mobile app	Under 1 minute	YES	YES

SLHT	NO – meter	Under 1 minute	NO	NO
HRT	YES	Under 5 minutes	YES	NO

Q4: Based on the findings, only the Heel Raise Test does not require any equipment. On the other hand, the equipment required for conducting most of the other tests is readily available. Based on the theoretical section, this equipment includes a chair, a timer, a meter, a tape. The CMJ presented a challenge in assessing the jump height, primarily due to the requirement for additional space to capture the frame with a camera, which was mostly problematic.

Q5: No test was time-consuming; the majority took less than a minute to perform. The SFT would likely take more than five minutes if all the tests were to be applied, primarily due to its complexity and focus on aspects beyond the patient's strength. However, if the tester focuses solely on the parts of the battery that are relevant to the thesis, no test takes more than 2 minutes.

Q6: The 30SST and 5XSST are strength-endurance focused tests, as indicated by the source used in theoretical section. Both SPPB and SFT include either the 30SST or 5XSST, as well. Additionally, they incorporate the 3m-walk test, 2-minute step test, or 8-foot up and go test, which stress the lower limbs, although their purpose may differ. The results of both batteries provide a more comprehensive view on the overall functional capacity of the patient [64, 108]. The SBJ and CMJ tests evaluate explosive strength along with other parameters. According to the theoretical section, the SLHT assesses the patient's strength, as well as balance, coordination, functional mobility, and motion control. However, the population frequently mentioned in correlation with this test is the one focusing on balance and the landing strategy as assessment for return to sports post-injury. [99, 100] The HRT focuses on strength-endurance, specifically targeting the calf muscles [116].

Q7: In the systematic review, five articles primarily focusing on children were found, with one of them utilizing two of the tests. Two articles employed the 30SST, two used the SBJ, and two utilized the CMJ. The SPPB and SFT are directly targeted at older adults, primarily through predetermined evaluation of results. According to Melo et al. [40], the 5XSST is also designed for older adults. The SLHT does not specify the age of the targeted populations. However, according to the results, this test particularly seemed to be problematic for the hospitalised children to perform. The sources providing information about HRT mostly describe the test in adults, but none of them specifically state the target population.

4.1. 30SST and 5XSST

The 30SST and 5XSST were successfully completed by most patients without any struggles in terms of strength. These tests are not time-consuming, as each took less than one minute to perform,

and did not require much space. They specifically targeted the patient's lower extremity strength – endurance and were not overly challenging for most children. The subjective level of exertion was rated as "very, very slight" four times, "slight" twice, and once each as "moderate", "somewhat severe" and "severe" with the 30SST, With the 5XSST, it was rated as "no exertion at all" once, "very, very slight" three times, "slight" twice, and "moderate" once. In the overall evaluation of all the questionnaire results, the 30SST emerge as the most favourable option.

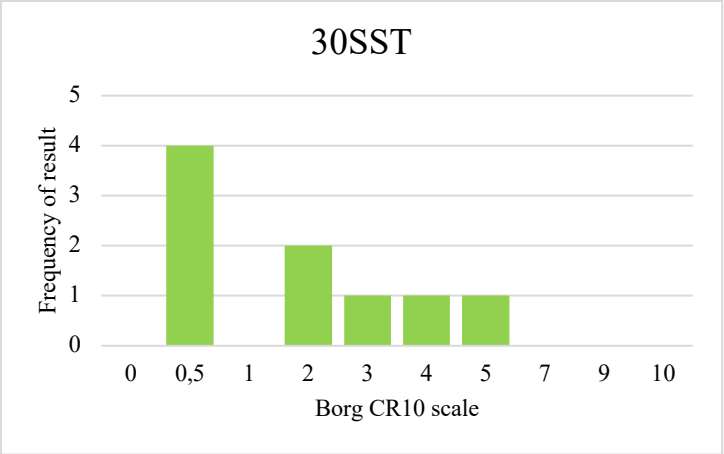

Figure 25 30SST – Borg CR10 scale

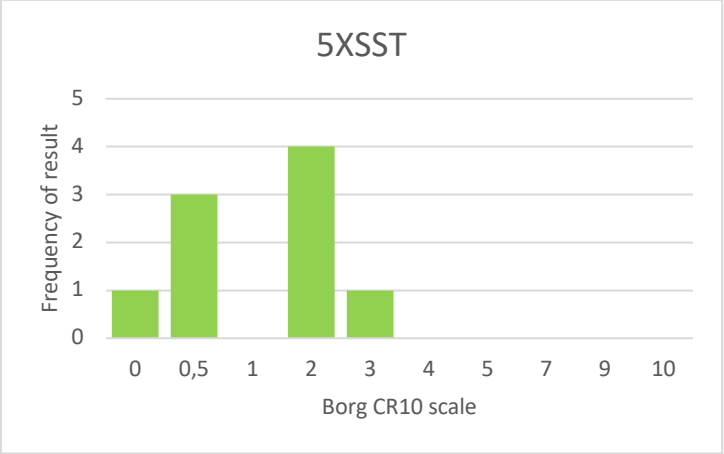

Figure 26 5XSST – Borg CR10 Scale

4.2. SPPB and SFT

Both the SPPB and SFT, as described in the theoretical section, are test batteries that focus on functional aspects beyond just strength. Initially, the intention was to assess each test within both batteries comprehensively, but due to limitations in patient endurance and comfort, as well as to save time during testing, only tests specifically targeting lower extremity performance were included. The remaining untested components of the battery are considered space-saving.

The SPPB involved a 3-meter walk test, which was applicable for 8 out of 10 patients. However, 2 patients could not complete it due to furniture layout and catheter tube length. Those who completed the test did so without difficulty and rated it with the lowest numbers on the scale. It was rated as “no exertion at all” six times, “very, very slight “once, and “slight” once. All patients were able to perform the balance positions. The full battery, including the 30SST, could still be completed in under five minutes.

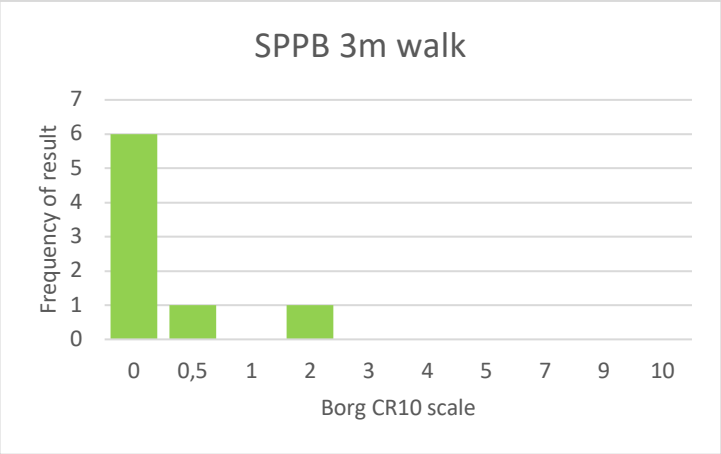

Figure 27SPPB 3m walk - Borg CR10 Scale

In the SFT, both the 8-foot up and go and 2-minute step test were examined. The 8-foot up and go test was applicable for 7 out of 10 patients. The remaining 3 were unable to complete the test due to the same reason mentioned with the 3-meter walk test, as the path was 2,43 meters. It was rated as “no exertion at all” four times, “very, very slight” twice, “slight” once, and “moderate” once on the scale. The 2-minute step test was fully possible to complete due to its small space requirement, but it turned out to be the most demanding test for the patients. Six out of 10 patients struggled to raise their knees to the desired height, and they complained about the length of the test. The 2-minute step test was the only one that presented problems in terms of adherence and motivation for the younger children to complete it. Only one patient rated the test “slight” exertion, while the rest of the patients rated it as “moderate” three times, “somewhat severe” three times and “severe” once on the scale. Three out of the 10 patients did not manage to complete the test at all.

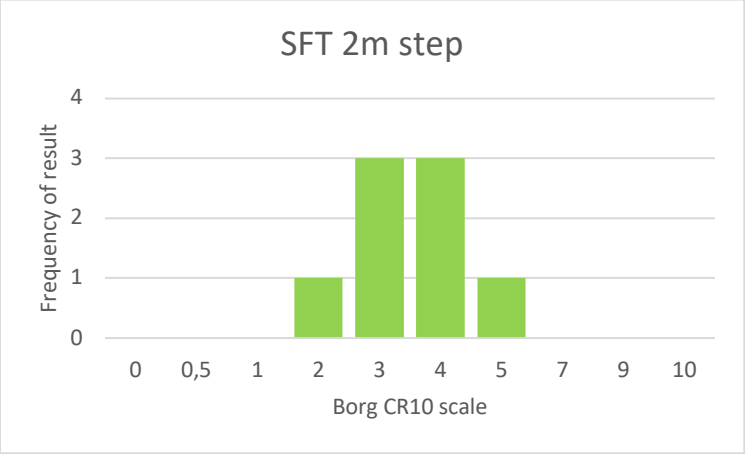

Figure 28 SFT 2m step - Borg CR10 Scale

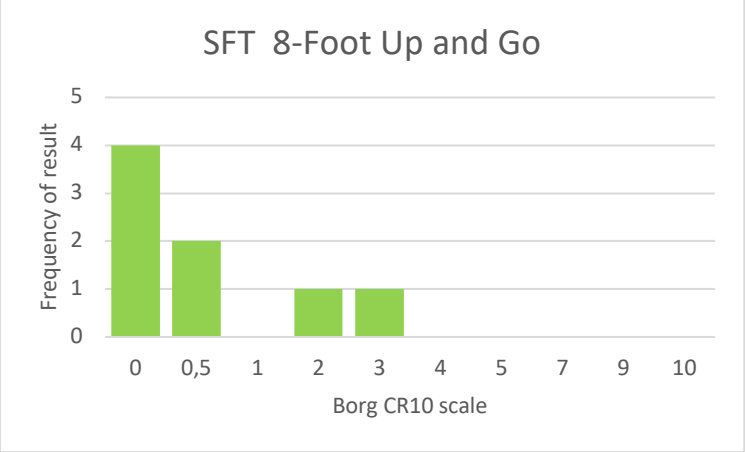

Figure 29 SFT 8 – Foot Up and Go – Borg CR10 Scale

4.3. SBJ

The SBJ posed challenges in several areas. Six out of 10 patients were not able to complete this test. Some rooms lacked sufficient space for jumping, while others were large enough but presented issues with the length of the catheter tubing. Unlike the tests involving walking, attempting to accommodate the tube length during the sudden movement of the jump felt more hazardous. When space was available for jumping, another issue arose: some patients were unable to perform the test. One patient experienced thigh pain, while another was prohibited from jumping due to compression fractures of the vertebrae. Only 4 patients were able to undergo testing without experiencing any limitations due to the catheter tubing or jumping restrictions. The subjective exertion differed a lot with this test. One patient rated it as “no exertion at all”, one as “very, very slight”, but two as “somewhat severe”.

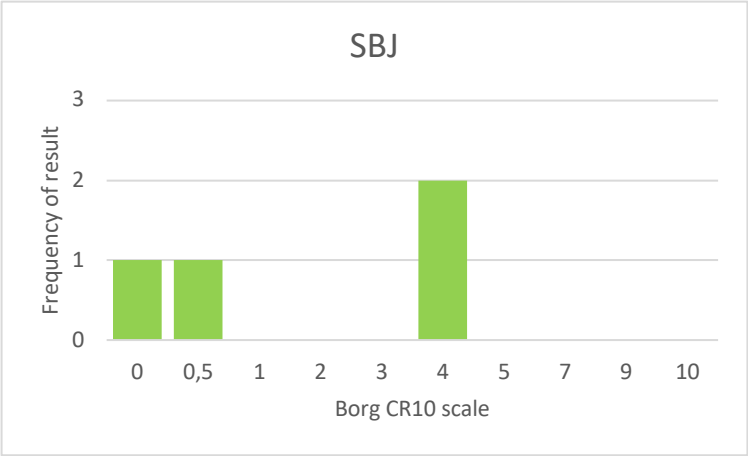

Figure 30 SBJ - Borg CR10 Scale

4.4. CMJ

The CMJ was attempted with 5 patients, and the test always posed some difficulties. It was once subjectively rated as “very slight”, twice as “slight”, twice as “moderate” and once as “severe”. Objectively, the patients had problem managing a proper jump. The main issue was discovered, when it turned out that the mobile application does not accurately measure jump height. Therefore, the test cannot be evaluated without special equipment. On the other hand, it primarily evaluates strength, require less space, and most patients did not find it that much challenging. However, the result could be affected by the technique of the jump, leading to potential error in evaluation. If special equipment such as the contact plates is available to the tester, the test would be significantly more worthy of consideration.

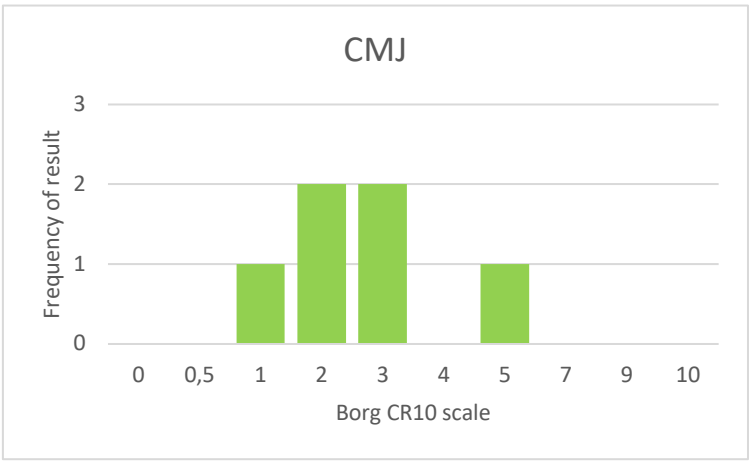

Figure 31 CMJ – Borg CR10 Scale

4.5. SLHT

The SLHT could not be performed by any of the patients, mainly due to the reasons mentioned earlier regarding space limitations and catheter tubing. Additionally, most patients found it challenging to balance on one leg. When they managed to jump, they landed on both feet, and the attempt could not be counted, rendering the test too difficult for them. Moreover, this test does not primarily target paediatric population or assess strength, making it not very suitable for the purpose of the study.

4.6. HRT

The HRT was properly tested only by patient II because other patients could not perform a countable attempt of the heel raise. Also, due to the frequent absence of a free wall, some patients struggled with worsened stability. This test is the only one that doesn't require any equipment and primarily targets strength. However, it turned out to be unnecessarily difficult for the patients and it does not target the paediatric population either. The graph evaluating The Borg CR 10 scale is not conclusive in this case. However, the only patient that performed the test, rated it as "severe".

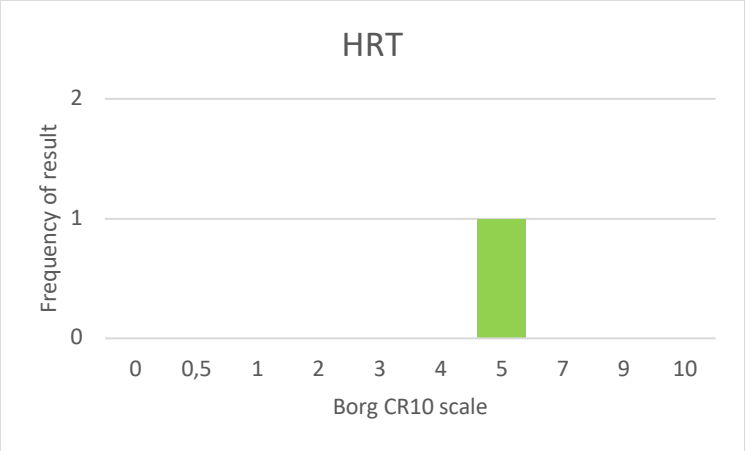

Figure 32 HRT – Borg CR10 Scale

5 DISCUSSION

The initial focus of the search was solely on strength-endurance tests. However, it became apparent that the most utilized tests for this purpose were limited to the 30 – second sit-to-stand test or the 5 times sit-to-stand test. Consequently, the scope of the search was broadened to include tests dedicated to the explosive strength and function of the lower extremities.

This thesis does not evaluate the results of the tests themselves, due to the lack of standardised data and modifications of the hospital settings. Instead, it notes only the possibilities of their application, highlighting the need for further research in evaluating the tests.

In the systematic review conducted for the thesis, the TUG test was excluded due to insufficient information regarding its applicability as a lower extremity strength test, and none of the reviewed studies utilized it for this purpose. During the development of the thesis, the 8-foot up and go test, a modified version of the same test that shortens the distance from 3 to 2,44 meters, was used, due to the effort to evaluate all aspects of the SFT related to the lower limbs. Even though, the 8-foot up and go test is not primarily testing strength, it was important to include it due to its large space requirement. With further research into the potential applicability of the TUG as a strength test, based on the successful testing of its modification, it can be assumed that it would feasible under specified conditions.

The results of all the tests involving a chair (30SST, 5XSST, 8-foot up and go) were affected because there was only one type of chair available, which did not meet the conditions properly due to its height. Some patients were unable to lean their backs against the chair as required by the test. Some of them even struggled to get up on the chair, which made the whole test much harder and exhaustive and some of the patients didn't finish the test because of it. The only chair available in the hospital department had a seat height of 47 cm. For more accurate results of the 5XSST and 30SST, a proper chair is needed. Along with the results themselves, the subjective evaluation was most likely affected as well. However, based on the questionnaire results, these two tests still seem to be the relevant and applicable.

In testing HRT, the variant involving a maximal number of lifts was applied. However, the variant used by Miaskowski, C., et al. [117], in their study, mentioned in the theoretical section, which involves a predetermined amount of time for each test, appears to be more practical. When patient II was tested, he struggled with lifting his heels, and there were time gaps between individual attempts because no time limit was set.

When choosing between tests 30SST and 5XSST, based on research in the theoretical section, Bohannon [2] mentions that the 5XSST or any modification involving a specific number of repetitions appears to be more accurate than performing the maximum number of repetitions within a predetermined time frame, provided that the patient has sufficient strength to complete the predetermined number of repetitions.

The primary identified issue was the central catheter tube, which was present in 8 out of 10 patients. However, only two had tubes so short that they posed restrictions during gait tests. The jump tests presented more challenges due to the rapid movement and the risk of catheter rupture.

During the data collection of the experimental section, it became evident that the intensive examination, comprising five to eight tests, was too demanding for patients with the diagnoses. They experienced fatigue and likely did not perform as they would have if they were fully rested. Additionally, the testing had a negative impact on two patients. Subsequently, further measurements were conducted with longer intervals between each test, and the testing was stopped immediately, when the patients felt exhausted.

Among the tests, based on the description of the testing and the questionnaire, the 30-Second Sit-to-Stand Test emerges as the most ideal, with the fewest complications, rendering it the most applicable in a specified setting. Additionally, it can be used in the paediatric population and primarily assesses the patient's strength. However, also suitable for further research are the 5 Times Sit-to-Stand Test, Short Physical Performance Battery, Senior Fitness Test and Standing Broad Jump. It greatly depends a lot on the patient’s current condition and the conditions in their hospital room.

To compare and discuss the findings of this thesis, it is important to note the absence of studies directly specified on this theme. To elaborate, Thams et al.[119] focus in their thesis on the test-retest reliability of five tests among healthy children aged between 6-9 years. Three of the mentioned tests are 30SST, SBJ and squat jump (it is not quite clear, whether it can be considered as CMJ). The authors found a high test-retest reliability in the jump tests. However, they observed low retest reliability in 30SST. The results of these two theses cannot be directly compared due to different intentions, but it is beneficial to consider these results in future research.

Consequently, the discussion is constrained by limitations inherent to the measurement techniques and by certain circumstances that affected the results. These factors must be considered when using the knowledge of the thesis among future research.

.

6 CONCLUSION

In the duration of this thesis, a total of 449 articles were reviewed, and under specified conditions, they were gradually filtered down to a final number of 84 studies. The articles were required to included strength tests for lower extremities applicable within a maximum area of 5 m^2 and without the need for specialised equipment. In total, 8 tests or batteries were found and described in the theoretical section of this thesis. The primary intention was to document articles that utilize these tests for children, but unfortunately, only 5 articles fulfilled this condition. The two studies utilize the 30s-SST, two employ the broad jump test and one uses the countermovement jump. The remaining 5 tests or batteries were primarily used across various populations such as tumor survivors, older adults in a risk of fall and other. The 30s-SST was the most significantly used test among all studies, appearing in 36 studies independently and in three others as part of the SFT.

The primary result of this thesis is based on a questionnaire, answered with the results of testing 10 patients, which include the use of a group of tests chosen based on the systematic review. The testing results were recorded, and the duration along with any eventual complications were described.

Based on the questionnaire, the 30SST appears to be the most applicable along the performed tests. The 5 Times Sit-to-Stand Test, Short Physical Performance Battery, Senior Fitness Test and Standing Broad Jump seem to be, in most cases, suitable as well.

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10 ABBREVIATIONS

30SST	30-second sit-to-stand
ALL	acute lymphoblastic leukaemia
5XSST	five times sit-to-stand
SPPB	short physical performance battery
ADT	androgen deprivation therapy
SBJ	standing broad jump
CMJ	countermovement jump
SLHT	single leg hop test
SFT	senior fitness test
HRT	heel raise test