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Original Scientific Article

Measuring the Impact of COVID-19 on Young Adult Functional Capacity: A Comparative Study of Walking and Step Endurance Tests

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Abstract

Objectives. This study aimed to evaluate and compare the functional capacity of young adults recovering from COVID-19 using the 6-Minute Walk Test (6MWT) and 2-Minute Step Test (2MST), focusing on cardiovascular parameters, and to examine correlations between these tests, demographic factors, and muscle strength.

Materials and methods. A cross-sectional study was conducted with 34 young participants (mean age: 20.62 years, 88.24 % female), all experiencing mild post-COVID-19 symptoms. Muscle strength (grip and quadriceps strength) was assessed, and functional capacity was evaluated using the 6MWT and 2MST, with the test order randomized by drawing lots. Hemodynamic responses, fatigue, and dyspnea were measured before and after both tests. Paired t-tests were used to compare cardiovascular parameters and leg fatigue between the 6MWT and 2MST. Pearson's correlation coefficient assessed relationships between both tests, demographics, and muscle strength.

Results. The study revealed an increase in heart rate and leg fatigue after the 6MWT compared to the 2MST, whereas systolic blood pressure was elevated following the 2MST compared to the 6MWT. The 6MWT showed a significant positive correlation with the 2MST ($r = 0.350$, $p = 0.043$). Additionally, quadriceps strength was positively correlated with both the 6MWT ($r = 0.372$, $p = 0.030$) and the 2MST ($r = 0.395$, $p = 0.021$).

Conclusions. The findings of this study indicate that both the 6MWT and 2MST are effective in assessing functional capacity in young individuals recovering from COVID-19, showing distinct physiological responses. Furthermore, quadriceps strength is correlated with both tests, highlighting the importance of muscle strength in recovery.

Keywords: COVID-19, physical fitness tests, functional fitness, cardiorespiratory endurance.

Introduction

Severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) primarily affects the respiratory system, but it also causes systemic symptoms, such as fatigue, muscle weakness, and exercise intolerance, that can persist for over 4 weeks or even months in many individuals following the acute phase of infection (Parotto et al., 2023; Weldon et al., 2023). These long-term effects extend beyond lung function, significantly impairing recovery, functional capacity, and quality of life (Alahmari et al., 2023), while also complicating rehabilitation despite normal lung function (Daynes et al., 2024; Wade, 2020). For young adults recovering from COVID-19, assessing functional capacity is essential to identify physical impairments and guide rehabilitation. This evaluation highlights obstacles to daily activities and directs interventions to promote full recovery (Torres-Castro et al., 2023).

Assessing fitness components, especially cardiorespiratory fitness, is vital for precise exercise prescription (Harber et al., 2024; Kaminsky et al., 2024; Ross et al., 2016). It is closely linked to cardiovascular health and is a key indicator of the risk of cardiovascular events and mortality. Evaluating

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this fitness component allows for personalized interventions that reduce health risks and improve long-term well-being (Harber et al., 2024). In clinical practice, cardiorespiratory fitness is often assessed using tests that require advanced equipment, such as treadmills or cycle ergometers, which may not be available in resource-limited settings (Noonan & Dean, 2000). Time-limited walking, sit-to-stand, and step tests are essential for assessing functional status and prognosis in individuals with cardiorespiratory conditions. These tests are safe, effective, and offer critical insights into submaximal exercise capacity, endurance, and daily functional ability, which are key for managing chronic conditions and improving quality of life (Andrade et al., 2012; Cruz-Montecinos et al., 2024; Torres-Castro et al., 2023). For this reason, tests based on the ability to perform daily living tasks are gaining popularity for assessing cardiorespiratory fitness. Functional assessments, particularly walking tests, play a vital role in evaluating daily task performance and overall physical function (Medicine, 2013), especially in post-COVID-19 recovery. Walking requires the coordination of cardiovascular and musculoskeletal systems, and impairments can increase energy expenditure and oxygen demand, complicating recovery (Singh et al., 2014). The 6-Minute Walk Test (6MWT) widely used in clinical settings, measures submaximal aerobic endurance, offering key insights into cardiovascular and muscular function, particularly in cases of heart failure and pulmonary diseases (American Thoracic Society, 2002; Casillas et al., 2013; Holland et al., 2014).

The 6MWT is a simple, cost-effective test that evaluates walking capacity and daily activity performance. Although practical and versatile, it requires a 30-meter hallway and can be time-consuming for routine outpatient visits (Jones & Rikli, 2002; Poncumhak et al., 2023). The 2-Minute Step Test (2MST) is a popular alternative, especially for patients unable to complete the 6MWT. It requires minimal space and no special equipment, making it suitable for resource-limited settings (Bohannon & Crouch, 2019; Jones & Rikli, 2002). It involves marching in place with high knee lifts, providing a less demanding method to assess aerobic endurance (Jones & Rikli, 2002). However, there's no clear consensus on which test provides a more accurate functional assessment, as studies have yielded mixed results. The 2MST replicates physically demanding daily activities, such as stair climbing, which is especially challenging for heart failure patients (Węgrzynowska-Teodorczyk et al., 2016) and older adults (Poncumhak et al., 2023) compared to walking on flat surfaces. Some authors suggest that it should be used as a complement rather than a substitute for other fitness assessments (Węgrzynowska-Teodorczyk et al., 2016). This approach offers valuable insights into functional capacity and real-life physical performance. The objective of this study was to evaluate and compare the physical functional capacity of young adults recovering from COVID-19 using the 6MWT and 2MST, with a focus on cardiovascular parameters. Additionally, the study aimed to explore the correlations between these tests, demographic factors, and muscle strength in post-COVID-19 young adults.

Materials and Methods

Study Participants

This cross-sectional analytical study calculated the sample size using a dependent t-test in G*Power version 3.1.9.4, with an alpha level set at 0.05 and a power of 0.80. A total of 34 participants (30 females and 4 males, aged 18 to 25 years) were recruited through face-to-face contact and posters. These participants were outpatients with mild post-COVID-19 symptoms, having been diagnosed with COVID-19 that did not require hospitalization and discharged within four weeks before evaluation. Exclusion criteria included pre-existing cardiorespiratory, neurological, or musculoskeletal conditions that could influence test performance, a body mass index (BMI) over 30 kg/m^2, and oxygen saturation (SpO_2) levels below 95 %. The study was approved by the University of Phayao Ethics Committee (reference number: HREC-UP-HSST 1.2/089/67).

Study Organization

In the initial phase of the study, participants were interviewed to collect data on age, medical history, and their experience with COVID-19. Anthropometric measurements (height, weight, and BMI), sociodemographic details (age, gender), and clinical information (comorbidities, smoking status, exercise habits) were also recorded. Vital signs, including heart rate (HR), blood pressure (BP), and peripheral oxygen saturation (SpO_2), were measured. Hand grip strength and quadriceps muscle strength were assessed. Functional capacity was evaluated using the 6MWT and 2MST by blind assessors, uninvolved in the interviews.

Grip Strength

Grip strength was measured using a dynamometer (T.K.K 5001 Grip-A, Takei Scientific Instruments, Niigata, Japan), a standard tool with excellent reliability commonly used to assess upper limb strength in adults (Horn et al., 2024). Participants squeezed the device with their dominant hand for three seconds while standing with their arm straight and slightly abducted. The test was repeated three times, with one-minute rest intervals, and the highest score (in kilograms) was recorded (Savas et al., 2023).

Quadriceps Muscle Strength

Quadriceps muscle strength was assessed using a hand-held dynamometer (Model-01165, Lafayette Instrument Company, Lafayette IN, USA), a reliable and valid tool for measuring isometric lower limb muscle strength and power in adults (Mentiplay et al., 2015). The participant, seated with the hip and knee flexed at 90 degrees, performed maximal isometric knee extension with the dominant lower extremity. The test was repeated at least three times, and the highest recorded value (in kilograms) was documented (Brown & Weir, 2001).

Functional Capacity

Participants completed the 6MWT and 2MST on the same day, with a 30-minute rest interval between the tests to reduce muscle fatigue. The order of the tests was randomized by drawing lots. Prior to and immediately after each test, participants were seated, and their SBP, DBP HR and SpO_2 were recorded. Participants also rated their subjective levels of fatigue and dyspnea using a modified 10-point Borg scale,

and dyspnea was assessed with the Borg Rating of Perceived Exertion (RPE) scale (6-20 scale).

6MWT

Before the test, participants were given at least 10 minutes of rest in a seated position to ensure they were adequately prepared. The test was conducted along a 30-meter corridor, and participants were instructed to walk as far as possible within a 6-minute period. Running was prohibited, and participants were encouraged to walk at a comfortable pace, with the option to slow down or stop briefly if needed. The total distance covered during the 6MWT was measured and recorded to assess physical functional capacity (American Thoracic Society, 2002).

2MST

Participants rested for at least 10 minutes before the test. After a brief familiarization session, they marched in place for two minutes, lifting their knees to a height between the patella and iliac crest. They could use support and adjust speed as needed. The investigator counted the steps on the right knee, with the final score representing the total number of steps where the knee reached the specified height (Jones & Rikli, 2002).

Statistical Analysis

Data analysis was conducted using Stata version18. Descriptive statistics, including mean, standard deviation, and frequency, were used to summarize participants' demographic and clinical characteristics. Paired t-tests were employed to compare HR, SBP, DBP, and leg fatigue between the 6MWT and the 2MST, while the Signed Rank Test was used for SpO_2 and dyspnea measurements. Pearson's correlation coefficient was calculated to examine the relationships between 6MWT and 2MST outcomes, demographic factors (age, weight, height, BMI), and muscle strength (hand grip and quadriceps strength). A p-value of less than 0.05 was considered statistically significant.

Results

Table 1 presents the clinical characteristics of 34 participants recovered from mild COVID-19. The mean age was 20.62 years, with 88.24 % being female. The average height, weight, and BMI were 159.88 cm, 54.97 kg, and 20.21 kg/m², respectively. Participants were 3.70 ± 6.38 months post-recovery. Most participants (91.18%) were non-smokers, and 17.65 % reported exercising ≥3 days per week. Functional capacity was evaluated using the 6-Minute Walk Distance (577.76 ± 29.02 meters), the 2-Minute Step Test (115.76 ± 13.44 repetitions), quadriceps strength (20.31 ± 4.85 kg), and handgrip strength (22.83 ± 7.26 kg).

The 6MWT resulted in a significantly higher final HR (120.41 ± 19.68 bpm) compared to the 2MST (111.09 ± 16.74 bpm, p = 0.009). SBP was significantly higher at the end of the 2MST (131.74 ± 17.16 mmHg) than the 6MWT (124.97 ± 14.94 mmHg, p = 0.006). There was no significant difference in DBP between the 2MST (81.41 ± 9.37 mmHg) and the 6MWT (79.15 ± 7.66 mmHg, p = 0.05). Dyspnea scores showed no significant differences between the two tests at baseline (p = 0.07) or at the final stage (p = 0.20). However, leg fatigue was significantly lower in the 2MST (2.59 ± 1.12) compared to the 6MWT (3.34 ± 1.52, p = 0.007) (Table 2).

Table 1. Clinical and functional characteristics of 34 mild-post COVID-19 individuals

Characteristics	n (%) or Mean ± SD	Min-max
Age (years)	20.26 ± 0.61	
Sex (female)	3.000 (88.24)	
Height (cm)	159.88 ± 8.22	
Weight (kg)	54.97 ± 15.31	
BMI (kg/m²)	20.21 ± 5.48	
Duration after COVID (months)	3.70 ± 6.38	
No coexisting diseases	34.00 (100)	
Smoking history		
No smoker	31.00 (91.18)	
Active smoker	2.00 (5.88)	
Former smoker	1.00 (2.94)	
Exercise habits, number		
≥3 days/week	6.00 (17.65)	
1-2 days/week	15.00 (44.12)	
No exercise	13.00 (38.24)	
Physical measures		
6MWD (meters)	577.76 ± 29.02	523.00 - 624.00
2MST (repetitions)	115.76 ± 13.44	76.00 - 185.00
Quadricep strength (kg)	20.31 ± 4.85	14.00 - 32.50
Grip strength (kg)	22.83 ± 7.26	12.00 - 42.10

BMI, body mass index; 6MWD; 6-minute walk distance, 2MST, 2-minutes step test, kg; kilogram

Table 2. Comparison of hemodynamic responses, fatigue, and dyspnea severity to 6MWT and 2MST in mild-post-COVID-19 individuals

Variables	2MST	6MWT	p
HR baseline (bpm)	91.24 ± 12.19	89.27 ± 13.27	0.29
HR final (bpm)	111.09 ± 16.74	120.41 ± 19.68	0.009*
SpO_2 baseline (%)	97.88 ± 0.17	97.71 ± 0.16	0.37
SpO_2 final (%)	98.03 ± 0.83	97.74 ± 0.79	0.13
SBP baseline (mmHg)	115.77 ± 13.44	112.71 ± 13.65	0.06
SBP final (mmHg)	131.74 ± 17.16	124.97 ± 14.94	0.006*
DBP baseline (mmHg)	75.85 ± 9.24	75.59 ± 8.86	0.64
DBP final (mmHg)	81.41 ± 9.37	79.15 ± 7.66	0.05
Dyspnea baseline (6-20 grade)	6.47 ± 0.86	6.15 ± 0.36	0.07
Dyspnea final (6-20 grade)	11.15 ± 2.11	11.85 ± 2.39	0.20
Leg fatigue baseline (1–10 grade)	0.21 ± 0.43	0.15 ± 0.42	0.16
Leg fatigue final (1–10 grade)	2.59 ± 1.12	3.34 ± 1.52	0.007*

Values are presented as mean ± standard deviation. 6MWD, 6-minute walk distance; 2MST, 2-minutes step test; HR, Heart rate; bpm: beats per minute; SpO_2, Oxygen saturation; SBP, systolic blood pressure; DBP, diastolic blood pressure. *p<0.05, statistically significant

Table 3. Relationships of 6MWT and 2MST with demographic parameters and muscle strength in mild-post-COVID-19 individuals

Variables	Correlation coefficient	6MWD (m)	2MST (no.)
2MST (no.)	r	0.350	
	p-value	0.043*	
Age (years)	r	0.098	-0.007
	p-value	0.581	0.967
Height (cm)	r	0.182	-0.140
	p-value	0.302	0.429
Weight (kg)	r	0.079	-0.140
	p-value	0.658	0.430
Quadricep strength (kg)	r	0.395	0.372
	p-value	0.021*	0.030*
Grip strength (kg)	r	0.250	0.091
	p-value	0.153	0.611

2MST, two minutes step test; 6MWD, six-minute walk distance; kg, kilogram; cm, centimeter; *p<0.05, statistically significant

Table 3 shows the relationships between the 6MWT and 2MST and various demographic and strength parameters in mild post-COVID-19 individuals. A significant positive correlation was found between the 6MWD and 2MST ($r = 0.350$, $p = 0.043$). Both the 6MWD and 2MST showed significant positive correlations with quadriceps strength (6MWD: $r = 0.395$, $p = 0.02$; 2MST: $r = 0.372$, $p = 0.03$). However, no significant correlations were found between the tests and age, height, or weight ($p > 0.05$). Similarly, grip strength did not show significant relationships with either test ($p > 0.05$).

Discussion

This study aimed to compare the physical capacity of young adults recovering from COVID-19 using 6MWT and 2MST, with a focus on cardiovascular responses, demographics, and muscle strength. Results indicated that the 6MWT significantly increased heart rate and leg fatigue, while the 2MST caused a notable rise in systolic blood pressure. Both tests were found to be correlated with quadriceps strength, highlighting their effectiveness in assessing physical function in post-acute COVID-19 recovery. These findings suggest that both tests can be valuable tools in guiding rehabilitation interventions and supporting functional recovery in this population.

The functional capacity measures, including the 6MWD, 2MST, quadriceps strength, and hand grip strength, provide insight into the participants' cardiovascular and muscular performance. The 6MWD (577.76 ± 29.02 meters) and 2MST (115.76 ± 13.44 repetitions) indicate good aerobic capacity and muscular endurance, as these values fall within the typical range for healthy young adults (Poh et al., 2006; Vaish et al., 2013). However, it is important to note that even among those with mild COVID-19, there may still be subtle, lingering deficits in muscular strength and aerobic performance, as shown by the lower quadriceps strength (20.31 ± 4.85 kg) and hand grip strength (22.83 ± 7.26 kg) when compared to non-infected peers (Tantibhaedhyangkul et al., 2020; Wang et al., 2018). This finding highlights the need for targeted rehabilitation strategies for individuals recovering from COVID-19 to restore full functional capacity.

Our study found that the 6MWT induced greater cardiovascular demand and muscular strain, as reflected by increased heart rate and leg fatigue following the test. These results are consistent with previous research, including studies by Reychler et al. (Reychler et al., 2018) and Troosters et al. (Troosters et al., 2002), which reported similar heart rate increases following the 6MWT. The increased cardiovascular response in the 6MWT can be attributed to the continuous movement and sustained weight-bearing nature of the test, both of which demand higher oxygen consumption and stimulate the cardiovascular system (Shephard et al., 1976). The significant leg fatigue observed post-test highlights the engagement of the quadriceps and lower limb muscles, underscoring the 6MWT's effectiveness in assessing both cardiovascular and muscular endurance. However, contrary to prior research, leg fatigue was notably higher after the 2MST than the 6MWT in patients with heart failure (Węgrzynowska-Teodorczyk et al., 2016) and older adults (Poncumhak et al., 2023; Srithawong et al., 2022).

The 2MST, though shorter in duration, led to significantly higher systolic blood pressure, pointing to a more intense, immediate response in terms of blood pressure regulation. The 2MST involves repetitive stepping at a fixed height and self-paced speed, focusing on lower-body muscles. Muscle contractions during the 2MST enhance venous return, increasing cardiovascular load. This muscle pump effect pushes more blood back to the heart, intensifying cardiovascular demands and leading to a greater rise in blood pressure compared to walking tests (Casey & Hart, 2008; Fisher & Secher, 2019). The biomechanics of the 2MST, requiring greater lower-body strength, coordination, and longer periods of single-leg balance, contribute to its higher physiological demands compared to the 6MWT (Beutner et al., 2015; Zhao & Chung, 2016). This discrepancy underscores the need for further investigation to better understand the comparative effects of these tests on muscular endurance and cardiovascular response.

These results show that the cardiovascular response differs between the 6MWT and 2MST. The 6MWT may better reflect sustained cardiovascular endurance, while the 2MST is more suited for short-term, high-intensity effort. Both tests are valuable for assessing post-COVID-19 recovery, with the 6MWT focusing on aerobic capacity and the 2MST on blood pressure regulation during exertion. Participants rated both tests below an RPE of 12, indicating low to moderate intensity. With RPE 12-13 correlating to 40-59 % VO_2 max (Medicine, 2013), both tests can be considered submaximal assessments, useful for monitoring recovery without overexertion

In young mild-post-COVID-19 individuals, the relationships between the 6MWT, 2MST, demographic parameters, and muscle strength reflect important insights into functional capacity. A significant positive correlation between the 6MWD and 2MST ($r = 0.350$, $p = 0.043$) suggests that both tests can be used interchangeably to assess functional performance in this population. This finding is

consistent with previous studies that have demonstrated the 2MST as an effective alternative to the 6MWT in assessing functional capacity, particularly in populations with mobility restrictions or post-illness recovery (Braghieri et al., 2021; Chow et al., 2023; Ishigaki et al., 2024) The 6MWT and 2MST assess different aspects of exercise capacity, but both demonstrate significant correlations with muscle strength. In our study, both the 2MST and 6MWD showed similar associations with quadriceps strength. These findings align with previous research that emphasizes the critical role of lower limb strength in functional performance, as stronger quadriceps are associated with better endurance and mobility (Poncumhak et al., 2023; Srithawong et al., 2022; Węgrzynowska-Teodorczyk et al., 2016) The lack of significant correlations with age, height, weight, and grip strength suggests that these factors might have less influence on functional outcomes in young, mild-post-COVID-19 individuals compared to more direct measures of lower body strength. This finding contrasts with studies on older populations, where weight and grip strength are often more strongly correlated with functional mobility (Kovarik et al., 2017; Kyomoto et al., 2019; Zhang et al., 2017). These results emphasize the importance of lower limb strength in functional performance in young individuals recovering from mild COVID-19. Future interventions may focus on strength-building exercises for the lower limbs to enhance recovery and prevent functional decline.

This study has several limitations. It primarily focuses on young adults with mild post-COVID-19 symptoms, limiting its relevance to more severe cases or older populations. The lack of long-term follow-up restricts the understanding of how physical function changes over time. Additionally, the study does not assess maximal oxygen consumption (VO2 max), which would provide a more precise evaluation of cardiorespiratory fitness. Future research should include more diverse populations, longer follow-up periods, and direct measurements of VO_2 max to better assess post-COVID-19 recovery.

Conclusions

The 6MWT resulted in increased heart rate and leg fatigue, while the 2MST led to a rise in systolic blood pressure post-test. Both tests were positively correlated with quadriceps strength, highlighting their utility in assessing and guiding recovery in post-acute COVID-19 patients.

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Conflict of Interest

The researchers claim no conflicts of interest.

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Оцінка впливу COVID-19 на функціональну здатність організму молодого дорослого населення: Порівняльний аналіз щодо застосування тесту з ходьби та степ-тесту у визначенні рівня фізичної витривалості

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 3 табл., 44 джерела.

Мета дослідження. Це дослідження мало на меті за допомогою тесту 6-хвилинної ходьби (6ХХТ) та 2-хвилинного степ-тесту (2ХСТ) оцінити та порівняти функціональну здатність організму молодого дорослого населення, що проходить період відновлення після COVID-19, акцентуючи увагу на параметрах серцево-судинної системи, а також дослідити кореляції між зазначеними тестами, демографічними факторами та м'язовою силою.

Матеріали та методи. Проведено поперечне дослідження за участю 34 молодих учасників (середній вік: 20,62 років, 88,24 % жінок), які мали легкі симптоми після перенесеного COVID-19. За допомогою тестів 6ХХТ і 2ХСТ оцінювали показники м'язової сили (сила хвату і сила чотириголового м'яза стегна), а також функціональну здатність, причому порядок проведення тестів визначався за методом випадкового відбору. Вимірювання показників гемодинамічних реакцій, втоми та задишки проводилось перед початком та після завершення обох тестів. Для порівняння параметрів серцево-судинної системи та втоми в нижніх кінцівках між 6ХХТ та 2ХСТ використовували метод t-критеріїв для парних вибірок. За коефіцієнтом кореляції Пірсона оцінювали взаємозв'язок між обома тестами, демографічними даними та м'язовою силою.

Результати. В рамках дослідження виявлено збільшення частоти серцевих скорочень і втоми в нижніх кінцівках після виконання 6ХХТ порівняно з 2ХСТ, тоді як після проведення 2ХСТ спостерігалося підвищення систолічного артеріального тиску порівняно з 6ХХТ. За результатами 6ХХТ встановлено значну позитивну кореляцію з 2ХСТ ($r = 0,350$, $p = 0,043$). Крім того, показник сили чотириголового м'яза стегна позитивно корелював як з 6ХХТ ($r = 0,372$, $p = 0,030$), так і з 2ХСТ ($r = 0,395$, $p = 0,021$).

Висновки. Результати цього дослідження свідчать про ефективність застосування 6ХХТ та 2ХСТ щодо оцінки функціональної здатності організму у молодих осіб, що проходять період відновлення після COVID-19, демонструючи чіткі фізіологічні реакції. До того ж, сила чотириголового м'яза стегна корелює з обома тестами, що підкреслює важливість показника м'язової сили у процесі одужання.

Ключові слова: COVID-19, тести для оцінки стану фізичної підготовленості, функціональна підготовленість, кардіореспіраторна витривалість.

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