Motor and Sensory Balance Deficits in Individuals Immediately After COVID-19, a Cohort Study

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Background and Purpose: Individuals with cardiorespiratory dysfunction demonstrate postural instability and increased risk of falls. Given that coronavirus disease (COVID-19) is commonly defined as a respiratory condition, it could be presumed that these patients may demonstrate similar balance deficits. This study aimed to determine deficits and characterize balance dysfunction (sensory or motor) in hospitalized patients classified as "COVID-19 recovered." **Methods:** Twenty-five participants consented for this study. Participants completed the Activity-Specific Balance Confidence Scale (ABC), a questionnaire about dizziness, the Timed "Up & Go" (TUG), and the modified Clinical Test of Sensory Interaction and Balance in a single session. The percentage of subjects who scored abnormal on the outcome measures was calculated. Correlations between demographics, respiratory function, and clinical outcome measures were determined using Spearman correlation coefficient. **Results:** All participants had abnormal scores on the TUG, 88% had abnormal scores on the ABC, and 48% of the subjects had abnormal scores on standing on foam eyes closed indicating difficulty using vestibular information. No correlation coefficient above 0.50 was found between the demographic information, respiratory function, and clinical outcome measures. **Discussion:** Clinical outcome measure scores did not correlate with respiratory function indicating that the deficits may be due to the extrapulmonary components of COVID-19. **Conclusion:** Both young and older adults presented with motor and sensory balance deficits acutely after COVID-19 infection. It is recommended that individuals acutely post–COVID-19 receive education and interventions to increase mobility, improve balance, decrease fall risk, and specifically receive activities that stimulate the vestibular system. **(Cardiopulm Phys Ther J. 2023;00:1–10)** *Key Words: COVID-19, balance, motor, sensory, respiratory*

INTRODUCTION

Coronavirus disease (COVID-19) is an infection caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that was first identified by researchers in Wuhan, China, in December 2019.[1] Initial signs and symptoms included fever, dry cough, and diffuse bilateral glassy lung opacities on pulmonary radiographs.[1] Medical professionals identified additional COVID-19 signs and symptoms, including pyrexia (85% of cases) and other respiratory symptoms, such as nasal congestion, dyspnea, and sore throat (4.8%, 18.6%, and 13.9%, respectively), suggestive of pulmonary pathologic processes.[1] Although COVID-19 was initially known as a pulmonary condition, it is now recognized as a complex disorder affecting multiple systems[2,3] and has been evidenced to display a wide array of extrapulmonary manifestations, including neurologic, thromboembolic, cardiovascular, renal, gastrointestinal, hepatobiliary, endocrinologic, and dermatologic symptoms.[4] Furthermore,

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Clinical Pearls

- This research is novel as it examined motor and sensory balance function in hospitalized patients, recently labeled as COVID-19 recovered.
- The findings implied that both young and older adults present with motor and sensory balance deficits acutely after COVID-19 infection.
- It is our recommendation that individuals acutely recovered from COVID-19 receive education and interventions to increase mobility, improve balance, decrease fall risk, and specifically receive activities that stimulate the vestibular system.
- It is also recommended that providers consider balance deficits and perceptions of balance function when planning for hospital discharge in individuals acutely recovered from COVID-19.

patients hospitalized with COVID-19 also present with musculoskeletal symptoms, including muscle weakness, myalgia, arthralgia, and exercise intolerance.[5,6] In those requiring intensive care, factors, such as inflammation, muscle disuse, and hypoxemia, contribute to generalized weakness.[4,5]

Evidence has demonstrated that individuals with COVID-19 frequently experience neurologic manifestations, which often occur early in the infectious process.[7-12] These manifestations can affect various aspects of the nervous system, including the central and peripheral nervous system.[3,9-11] The COVID-19 virus has been observed to possess neuroinvasive properties, as evidenced by reported signs and symptoms, such as headaches, dizziness, altered consciousness, epileptic crises, neuralgia, and ataxia.[13] Moreover, the virus's impact on the central nervous system can also manifest in conditions, such as acute viral meningitis, encephalitis, hypoxic encephalopathy, acute cerebrovascular disease, acute necrotizing hemorrhagic encephalopathy, and Guillain–Barré syndrome.[13] Vertigo, a specific type of dizziness, has also emerged as an additional symptom in COVID-19.[9] Notably, approximately 90% of individuals with COVID-19 experience at least one neurologic symptom, with common manifestations including gustatory and olfactory dysfunction, headaches, fatigue, muscle aches, altered mental status, and dizziness, among which headache, confusion, and dizziness are the most prevalent.[10]

Balance, defined as the ability to maintain an upright stance over a base of support in a given sensory environment, is controlled by the nervous system.[14] One's ability to maintain balance relies on the brain's integration of information from various sources, including the visual, vestibular, and somatosensory systems. However, if this intricate system is disrupted because of injury or disease, it can result in balance impairments that may be accompanied by additional symptoms, such as dizziness, vertigo, visual changes, nausea, fatigue, and challenges with concentration.[7] Given the previously mentioned symptoms and manifestations caused by the COVID-19 virus, it is reasonable to hypothesize that individuals with COVID-19 may also present with balance impairments. Furthermore, balance impairments have been documented in other pulmonary conditions, such as cystic fibrosis (CF), which is similar to COVID-19 in that it is primarily identified as a respiratory condition with systemic effects. Patients with CF have been shown to demonstrate imbalance because of variations in body composition due to nutritional deficits and musculoskeletal weakness, specifically in the quadriceps muscle.[15,16] Individuals with chronic obstructive pulmonary disease (COPD) can also present with extrapulmonary impairments, such as balance dysfunction, that often worsen with disease exacerbation.[17,18] As COPD progresses, additional systemic complications involving the cardiovascular and musculoskeletal systems are evident,[19] including dizziness and further deterioration of self-reliance, leading to an increased fear of falls.[20] There is also evidence that asthma is associated with falls suggesting balance impairments are present in this population as well.[21] There are existing studies that suggest balance dysfunction in patients with COVID-19.[22-28] However, most of the studies used questionnaires and were performed at least 1 month post–COVID-19. To the best of the authors' knowledge, there has only been one study that used objective assessments of balance, but most of these assessments were performed in the outpatient setting.[23]

As evidence continues to evolve on the clinical manifestations of COVID-19 across multiple body systems, it is imperative that physical therapists use multidomain functional assessments inclusive of balance. Although there are no validated balance assessments for individuals specifically affected by COVID-19, many validated balance assessment tools exist for individuals diagnosed with chronic obstructive pulmonary disease, including the Timed "Up & Go" (TUG)[29] and the modified Clinical Test of Sensory Interaction on Balance (mCTSIB).[30] To the researchers' knowledge, neither balance dysfunction nor its origin have been extensively studied in individuals acutely recovered from COVID-19 infection during hospitalization. The primary aim of this study was to describe balance deficits in hospitalized patients acutely recovered from COVID-19. The secondary aim was to describe the origin of the balance dysfunction (motor and/or sensory).

METHODS

This observational cohort study occurred at Duke University Hospital and was approved by Institutional Review Board for Human Subjects Protection (IRB Approval No. Pro00108353). Participants were identified from an electronic medical record system. See Table 1 for inclusion and exclusion criteria.

Potential participants were screened by a physical therapist (PT) to determine whether they met the criteria for inclusion in this study. Participants with 2 or more falls, as defined as unintendedly coming in contact with a

TABLE 1

Inclusion and Exclusion Criteria

Inclusion criteria	
	Age ≥18 y and <90 y
	Primary or secondary diagnosis of COVID-19 during hospitalization and off COVID-19 isolation (designated as "COVID-19 recovered" in EMR)
	Hospitalized in acute care setting
	Ability to ambulate 20′ with or without an assistive device without dropping >10% of resting SpO_2 (determined from existing PT evaluation)
	Ability to stand with no more than contact guard assistance (determined from existing PT evaluation)
	Not requiring the use of mechanical ventilation
	Minimum resting SpO_2 of 88% with or without supplemental oxygen
	No neurologic or orthopedic dysfunction that would affect balance
	Cognitively intact—able to follow directions and provide consent
Exclusion criteria	
	History of 2 or more falls in the year before COVID-19 diagnosis
	History of balance dysfunction

PT, physical therapist.

lower surface, were excluded. The Guideline for the Prevention of Falls in Older Persons, a joint endeavor of the American Geriatrics Society, the British Geriatrics Society, and the American Academy of Orthopaedic Surgeons, recommend that people with 2 or more falls be screened for fall risk whether they have observable gait and balance deficits.[31]

Participants in this study were identified as having an active COVID-19 infection using positive nucleic acid amplification (NAAT), polymerase chain reaction (PCR), or at-home COVID-19 antigen rapid tests. They were designated as "COVID-19 recovered" as defined by the World Health Organization (WHO) as the period when an infected individual's clinical symptoms resolve, and they meet the criteria for discontinuation of isolation or discharge from medical care.[32] Participants, in this study, were removed from isolation after 5 days for mildly ill patients or 10 days for moderately or severely ill patients per the Centers for Disease Control and Prevention's guidelines.[33] Furthermore, the WHO's clinical progression scale was used to assign an illness severity to each participant on a scale of 0 to 10 (0 = uninfected, 1–3 = ambulatory mild disease, 4–5 = hospitalized: moderate disease, 6–9 = hospitalized: moderate disease, and 10 = dead).[34] In addition to the type of COVID-19 testing and the WHO clinical severity score, data were also collected on the length of time since COVID-19 diagnosis and whether the participant was intubated and sedated during hospital admission. Eligible participants were seen for 1 session and completed the Activities-Specific Balance Confidence Scale (ABC),[35] the TUG,[36] the mCTSIB,[37] and a dizziness assessment. The assessments were conducted by 4 physical therapists, all of whom were trained by a physical therapist with over 30 years of experience who specializes in treating patients with gait and balance disorders and has expertise in the outcome measures. The participants first completed the ABC and dizziness assessment followed by the TUG and mCTSIB in a randomized order. If the participant was unable to read the ABC, the items were read to the participant. If the test was read to the participant, the therapists ensured understanding through verbal confirmation.

Vital signs, including heart rate (HR), respiratory rate (RR), oxygen saturation using pulse oximeter (SpO_2), blood pressure (BP), and mean arterial pressure (MAP), were measured at rest and at the completion of all physical performance measures. In addition, HR was measured after each outcome measure, and SpO_2 was continually monitored using pulse oximetry. If the participant required supplemental oxygen, the fraction of inspired oxygen (FiO_2) was titrated per physician orders. If SpO_2 dropped below the specified parameters on the order, participants were given a 3-minute seated rest break. If SpO_2 recovered above the specified parameters after the 3-minute rest break, activity resumed. If SpO_2 remained below the specified parameters after the 3-minute rest break or continued to drop with activity, FiO_2 was titrated to maintain SpO_2 per physician orders. The rate of perceived exertion (RPE) was measured using a 0 to 10 visual modified Borg scale after each physical performance measure. Participants were allowed time to rest if their RPE exceeded 5/10.

Clinical Outcome Measures

The ABC is a reliable and valid 16-item questionnaire that quantifies a person's balance confidence in performing common daily activities.[28-33,35-38] Higher scores indicate a higher degree of confidence. The ABC is reliable and valid.[35,39] Scores <80% indicate an increased risk of falls in individuals older than 65 years.[40] The ABC demonstrates concurrent validity in individuals with COPD[41] and is able to discriminate between fallers and nonfallers.[42]

Dizziness was assessed by first asking the participant "Have you experienced any dizziness in the past 24 hours?" If the participant responded "yes," both current level of dizziness as well as minimum and maximum levels of dizziness in the past 24 hours were rated using a 1 to 10 visual analog scale where higher scores indicated increased dizziness.[43] Participants were also asked to qualitatively describe their dizziness.

The TUG is a widely used physical performance test that measures the time it takes a participant to stand from a standard chair without armrests, walk 3 meters at a self-selected speed, turn around, walk back to the chair, and return to a seated position.[36] The TUG is reliable and valid in many populations, including individuals with COPD.[44-49]

Increased time to complete the TUG is indicative of a higher falls risk.[48] Scores >11 seconds indicate risk of future falls in older adults (older than 65 years),[39,50] and scores >8 seconds indicate risk of future falls in younger adults.[51] Participants were allowed to use their preferred assistive device, and the time to complete the TUG was recorded in seconds using a stopwatch. The test was repeated, if needed, at the discretion of the PT.

The mCTSIB is a validated tool used to assess a person's ability to use somatosensory, vestibular, and visual information to maintain balance by measuring the amount of time a person can stand under 4 conditions: 1 = eyes open on a firm surface, 2 = eyes closed on a firm surface, 3 = eyes open on a compliant surface, and 4 = eyes closed on a compliant surface.[37,52] A foam pad (Airex Balance Pad) was used as the compliant surface during the mCTSIB. The mCTSIB is both reliable and valid in many populations.[53-58] The inability to maintain stance for 30 seconds in each position is indicative of increased fall risk.[59,60] In this study, each condition was timed using a stopwatch for a maximum of 30 seconds. Rest breaks, if needed, were allowed between conditions, and one reattempt was allowed for each condition at the discretion of the PT.

Data Analysis

Descriptive statistics, means, standard deviations, and frequencies were calculated for demographic data, respiratory function, and clinical outcome measures. The percentage of subjects who scored abnormal on the clinical outcome measures was calculated using the criteria listed in Table 2.

To determine the use of sensory information, the results of the mCTSIB were interpreted according to Table 3.

The percentage of subjects abnormal in each condition was calculated. Correlations between demographics, respiratory function, and clinical outcome measures were determined using Spearman correlation coefficient. For a power of 0.80 using the Spearman correlation coefficient, the sample size was calculated to be 29 subjects using SPSS 28 (IBM, Armonk, NY).

RESULTS

Forty-five subjects met the inclusion criteria for this study, and 28 consented to participate. The reasons for not participating are presented in Table 4.

Three subjects were withdrawn from the study before data collection because they were no longer eligible for the study. One subject was receiving active treatment for cancer which could affect balance, and the other 2 subjects were discharged from the hospital before data collection. Descriptions of demographic data, respiratory function, and results of clinical outcome measures are listed in Table 5 and Table 6.

Individual participants' type of COVID-19 test, time since COVID-19 diagnosis, WHO COVID-19 clinical severity score, intubation/sedation history, and vital signs are presented in Table 5. Most participants were characterized as having moderate disease; however, 3 participants were classified as having severe disease. Only 4 participants were intubated and sedated during hospital admission.

As presented in Table 7, there was no correlation between the order of the test and the scores on the clinical outcome measures; therefore, the scores were collapsed and analyzed together.

The number and percentage of subjects who scored abnormal on the clinical outcome measures are listed in Table 2. One hundred percent of the subjects had abnormal scores on the TUG, indicating deficits in the motor aspects of balance. Eighty-eight percent of the subjects had low confidence in their ability to balance. The number and percent of subjects having difficulty using sensory information for balance based on the mCTSIB are listed in Table 2. Almost half of the subjects had difficulty using vestibular information for balance.

The correlations between the demographics and respiratory function with the clinical outcome measures are presented in Table 7. No correlation coefficient was above 0.50. Two correlations that were significant ($P < .05$) included age and TUG (0.462) and change in FiO_2 and ABC (0.418). This may indicate that factors other than age, respiratory function, and dizziness contributed to the abnormal gait and balance scores.

TABLE 2

Abnormal Criteria for Clinical Outcome Measures With Number and Percentage of Subjects Who Scored Abnormal

Clinical Outcome Measure	Age <65 y	Age >65 y	Subjects Abnormal (n = 25)
TUG	8 s	11 s	25 (100%)
ABC	<90%	<80%	22 (88%)
mCTSIB Cond 1	<30 s	<30 s	0
mCTSIB Cond 2	<30 s	<30 s	2 (8%)
mCTSIB Cond 3	<30 s	<30 s	3 (12%)
mCTSIB Cond 4	<30 s	<30 s	12 (48%)

ABC, Activities-Specific Balance Confidence Scale; mCTSIB, Modified Clinical Test of Sensory Interaction on Balance; n(%); TUG, Timed "Up & Go."

TABLE 3
Interpretation of Performance on mCTSIB

Sensory Use	Interpretation
Normal	Normal on all conditions
Somatosensory	Abnormal on condition 2
Visual	Abnormal on condition 3
Vestibular	Abnormal on condition 4

mCTSIB, Modified Clinical Test of Sensory Interaction on Balance.

TABLE 4
Participants Reasons for Not Participating

Reason	No. of Participants
Not interested in participating	7
Self-reported history of falls	2
Anxiety	1
Discharged before contact by research team	5
Believed too weak to participate	1
Feared further exacerbation of condition	1
Non-English speaking	1
Self-reported peripheral neuropathy	1
Taken to operating room before contact by research team	1

DISCUSSION

In this study, individuals acutely recovered from COVID-19 seem to have both motor and sensory balance dysfunction. We hypothesize that these balance impairments are attributed to functional weakness from debilitation and respiratory dysfunction combined with difficulty using sensory information for balance. It is also possible that some balance dysfunction is due to impaired sensation or motor control, but neither was assessed in this study. Therefore, the clinical outcome measures may have overestimated sensory dysfunction in the participants. Clinical outcome measure scores did not correlate with respiratory function indicating that the deficits may have been due to the extrapulmonary components of COVID-19, such as sensory and neurologic impairments.

Similar findings to those of this study are seen in individuals with other respiratory conditions, but most notably in patients with COPD who demonstrate poorer balance and postural control compared with age-matched controls.[42,61-63] Similar to the participants in this study, individuals with COPD also have deficits related to extrapulmonary factors.[30,41,54,64,65] Researchers have found that these individuals had lower pain pressure thresholds[66] and impaired use of sensory information for balance.[42,66,67] Individuals with COPD demonstrate impaired balance and subsequent falls which are linked to sensory changes, such as proprioception[68,69] and verticality,[67] and motor changes.[65] In addition, cognition,[70] anxiety,[64,71] and depression[5,9] are also contributing factors to balance dysfunction and falls in this population. Hill and Goldstein[72] suggest that the increased demand for oxygen during balance and functional activities is the cause of the impairments. Yet others state that the balance impairments are caused by the sensory and motor deficits that accompany COPD.[66,68,69,73] The mechanisms for balance and functional impairments in individuals with COPD are unknown but may have a role in the deficits seen in individuals with COVID-19. Research seems to be inconclusive on the relationship between these balance impairments and respiratory function.[49,54,62-64,74,75]

The evidence on balance function in individuals with COVID-19 is limited, and no studies use objective measures of balance in hospitalized patients. Yilmaz et al[23] conducted a case–control study where objective assessments of balance, including computerized dynamic posturography, were performed on outpatients recovered from COVID-19. Twenty percent of the participants experienced dizziness potentially attributable to the vestibular or visual systems, but the dizziness was not classified as incapacitating vertigo.[23] Although our study was conducted in the acute care setting on an older population, this aligns with the findings in that the largest percentage of participants had difficulty using vestibular (48%) and visual (12%) information for balance. This suggests that these deficits may be more prevalent in older adults and/or may persist past the acute phase of COVID-19. Ludwig et al[22] examined individuals 6 months postdiagnosis of COVID-19 using the Dizziness Handicap Inventory and also found the presence of balance disorders during COVID-19. More specifically, reports of dizziness were common in the acute phase but became less persistent over time; however, women were more likely to experience dizziness than men, and their symptoms were more severe and persisted for longer periods of time.[22]

Other studies used subjective questionnaires to evaluate balance, dizziness, and vertigo in patients with COVID-19. Viola et al[24] found that 18.4% of patients reported balance disorders; of those, ~94% experienced dizziness and ~6% reported vertigo. Although Korkmaz et al[25] did not study balance specifically, they found that 31.8% of participants reported dizziness while only 6% reported true vertigo. This also aligns with a recent systematic review in which 7.2% of adults diagnosed with COVID-19 reported vertigo; however, balance and dizziness were not included in the scope of this review.[26] Interestingly, one case study reported that the only presenting symptoms were vertigo, nausea, and vomiting in the absence of pulmonary symptoms with the author recommending to suspect COVID-19 in the presence of vestibular symptoms.[28] Although there are few high-quality studies that examine balance in individuals with COVID-19, the evidence is evolving and the findings are consistent with this study suggesting that the balance impairments are more likely due to the extrapulmonary nature of the condition. Furthermore, low balance confidence scores on the ABC, which is known to be associated with increased fall risk,[76] were seen in the

TABLE 5

Individual Participants' Type of COVID-19 Test, Time Since COVID-19 Diagnosis, WHO Clinical Severity Score, Intubation/Sedation History, and Vital Signs

Subject	Age (years)	Gender	Time Since COVID Diagnosis (days)	COVID test	WHO COVID Clinical Severity Scale	Intubated and Ventilated	Pretest HR
1	63	F	13	PCR/NAAT	5	No	92
2	65	M	50	PCR/NAAT	5	Yes	89
3	56	F	21	PCR	8	Yes	73
4	64	F	38	Rapid Test	6	No	98
5	65	M	30	Rapid Test	6	No	79
6	56	M	62	Home Rapid Test	4	Yes	112
7	33	F	5	Rapid Test	4	No	144
8	44	M	38	PCR	5	Yes	117
9	56	M	23	PCR	4	No	62
10	68	M	15	PCR/NAAT	4	No	82
11	40	M	49	NR	4	No	103
12	32	M	47	RNA	4	No	80
13	67	M	20	PCR	5	No	65
14	51	M	51	Rapid Test	4	No	105
15	50	M	65	PCR/NAAT	4	No	103
16	56	M	21	NR	6	No	74
17	60	M	33	NR	4	No	64
18	67	F	43	PCR/NAAT	4	No	85
19	59	M	22	PCR/NAAT	4	No	62
20	44	M	36	PCR/NAAT	4	No	91
21	38	M	39	NR	4	No	104
22	59	F	32	NR	5	No	80
23	73	F	25	PCR/NAAT	4	No	101
24	63	M	51	PCR	4	No	86
25	61	F	32	PCR/NAAT	4	No	105

Subject	Pretest BP	Pretest RR	Pretest SpO2 (%)	Midtest HR	Midtest SpO2 (%)	Posttest HR	Posttest BP	Posttest RR	Posttest SpO2 (%)
1	138/66 (90)	28	94	98	90	95	135/64 (88)	28	94
2	121/67 (85)	12	97	106	91	95	111/67 (82)	24	92
3	138/81 (100)	28	99	77	97	86	138/69 (92)	30	99
4	113/67 (82)	14	99	95	94	94	123/71 (88)	22	96
5	117/67 (84)	24	97	90	99	80	138/82 (101)	32	96
6	145/86 (106)	24	95	118	93	115	158/76 (103)	36	92
7	107/68 (81)	24	97	145	96	146	123/87 (99)	30	96
8	109/86 (94)	14	96	125	91	124	120/86 (97)	20	100
9	114/54 (74)	16	100	60	NA	62	119/55 (76)	20	100
10	103/70 (81)	32	87	90	92	92	105/41 (62)	40	98
11	128/91 (103)	30	100	133	100	115	127/99 (108)	31	100
12	124/75 (91)	28	98	90	97	88	135/83 (100)	32	99
13	125/75 (92)	18	98	81	98	75	123/75 (91)	22	93
14	102/59 (73)	12	94	110	92	110	105/70 (82)	18	93
15	134/104 (114)	24	94	111	94	107	137/93 (108)	38	92
16	117/67 (84)	18	97	82	100	84	128/70 (89)	24	100
17	134/104 (114)	18	96	64	96	64	134/80 (98)	26	100
18	113/67 (82)	20	98	92	100	90	128/72 (91)	24	96
19	117/68 (84)	36	95	64	98	69	123/78 (93)	44	97
20	123/75 (91)	14	99	93	99	94	104/66 (79)	20	0
21	138/96 (110)	28	100	99	100	93	138/101 (113)	30	100
22	114/78 (90)	20	94	84	97	84	124/85 (98)	23	93
23	155/84 (108)	12	100	109	100	110	143/66 (92)	24	100
24	130/77 (95)	18	94	80	95	81	124/76 (92)	28	94
25	125/66 (86)	24	95	116	92	116	127/60 (82)	24	94

TABLE 6

Demographic Data, Respiratory Function, and Clinical Outcome Measures

	Mean (SD)	Range
Age (yr)	55.6 (11.3)	32 to 73
Sex (number)	Males = 17, Females = 8	
Time since COVID-19 diagnosis (d)	34.44 (15.35)	5 to 65
Complaints of dizziness (number)	11 yes, 14 no	
FiO_2 Min (liters)	1.04 (2.07)	0 to 9
FiO_2 Max (liters)	2.20 (3.78)	0 to 15
# Subjects with change in FiO_2	7 yes, 18 no	
Pretest SpO_2 (percent)	96.92 (2.14)	94 to 100
SpO_2 change	0.40 (2.27)	−4 to 8
Max RPE	3.36 (2.49)	0 to 9
ABC (percent)	66.88 (17.61)	26.25 to 91.25
TUG (seconds)	20.57 (10.34)	10.42 to 46.00
mCTSIB eyes open firm surface	30.00 (0.00)	30 to 30
mCTSIB eyes closed firm surface	28.28 (6.24)	2.01 to 30
mCTSIB eyes open compliant surface	27.50 (8.08)	0 to 30
mCTSIB eyes closed compliant surface	19.41 (1.89)	0 to 30

ABC, Activities-Specific Balance Confidence Scale; mCTSIB, Modified Clinical Test of Sensory Interaction on Balance; RPE, rate of perceived exertion; TUG, Timed "Up & Go."

participants in this study, reinforcing the significance of these balance deficits; therefore, it is important to recognize decreased balance confidence and provide interventions to improve patient self-efficacy to reduce the risk of falls in individuals with COVID-19.

Strengths and Limitations

There were several strengths to this study. Although the sample size appears small, we did achieve a power for Spearman correlation of 0.74 calculated using SPSS 27 (IBM) indicating that the results are likely valid. All assessors in this study were licensed physical therapists and received specific training on administering the ABC, TUG, mCTSIB, and dizziness assessment. Furthermore, the order of the mCTSIB and TUG was randomized for each participant to distribute the fatigue effect over all tasks instead of the same later tasks.

There were also limitations to this study. Participants were recruited from a single large academic medical center, so the results may be affected by a higher complexity of care and may not be generalizable to all populations or regions. Because this was a descriptive study, the absence of a matched control group makes it difficult to ascertain whether the changes in balance observed in this population are specifically attributed to COVID-19 or the result of the hospitalization. Participants were excluded if they had a history of falls or balance impairments, but comorbidities, medications, and other factors may have been confounding variables. For instance, participants were not screened for

TABLE 7

Correlations Between Demographics and Respiratory Function With Clinical Outcome Measures

	ABC	TUG	mCTSIB Condition 2	mCTSIB Condition 3	mCTSIB Condition 4
Age	0.009	0.462[a]	−0.248	−0.191	−0.203
Order of test	−0.067	0.348	0.009	0.120	0.062
Time since COVID-19 diagnosis	0.010	0.008	0.195	0.093	0.059
Change in FiO_2	0.418[a]	0.049	−0.157	−0.044	−0.059
SpO_2 change	−0.155	0.158	−0.200	−0.339	−0.297
RPE Max	0.30	0.38	−0.074	−0.183	−0.299
Dizziness	0.020	0.193	−0.241	−0.297	−0.138

Spearman correlation coefficient.

[a]Significant at $P < .05$.

ABC, Activities-Specific Balance Confidence Scale; mCTSIB, Modified Clinical Test of Sensory Interaction on Balance; RPE, rate of perceived exertion; TUG, Timed "Up & Go."

postural hypotension, but it is noted that some participants displayed a decrease in BP postexertion. In addition, several participants had comorbidities, including diabetes mellitus, hypertension, asthma, obesity, COPD, gastroesophageal reflux disease, and osteoarthritis. These factors, along with the common medications used to treat these conditions, may have influenced a participant's performance on the balance tests.

Respiratory status was measured by FiO_2 and change in SpO_2 which may not be a true representation of the participants' lung function. This was necessary because not all participants received pulmonary function testing or arterial blood gas draws during their hospitalization, and no participants received these measures at the time the clinical outcome measures were performed in this study. Another limitation is that scores on the ABC may have been misleading. It is possible that participants rated their confidence on their baseline functional status instead of their current functional status, which was likely decreased because of hospitalization. Participants were screened for baseline mobility limitations through the electronic medical record, but inaccuracy is possible if participants chose to withhold information or if records were not properly updated. Finally, sensory and motor function were not measured due to time limitations and participant fatigue, but this information could have proven beneficial for better understanding of the participants' response to the balance tests.

Implications

It is important to understand that the COVID-19 virus affects multiple systems beyond the respiratory system resulting in extrapulmonary deficits, one of which is balance dysfunction. This study demonstrated that individuals acutely recovered from COVID-19 may have both motor and sensory balance impairments with more than 48% of participants having trouble using vestibular information for balance. This emphasizes the importance of performing multidomain functional assessments with individuals acutely recovered from COVID-19, especially assessments that address motor and vestibular balance deficits. The results from these assessments can better inform patient education, tailored intervention plans, and discharge planning.

Future Directions

Future research is necessary to better understand the role of specific sensory and motor impairments on balance dysfunction in people post–COVID-19. Exploring the sensory and motor function of individuals post–COVID-19 would provide additional information on the origin of the balance dysfunction. This may include tests such as proprioception, sensory thresholds (monofilaments), 30-second chair stand test (to measure lower extremity strength), and tests of verticality such as subjective visual vertigo. It would also be beneficial to have a control group and follow individuals long term to determine how balance function changes over time. Finally, expanding this research to large populations across different types of institutions would improve the generalizability of the results.

CONCLUSION

Both young and older adults acutely post–COVID-19 demonstrate motor and sensory balance deficits that may not be related to their respiratory function. These deficits may be due to immobility, deconditioning, or impairments of sensory or motor function. Participants have low perceptions of their balance function which may affect their function at hospital discharge. It is recommended that individuals acutely post–COVID-19 receive education and interventions to increase mobility, improve balance, and specifically receive activities that stimulate the vestibular system. In addition, balance deficits and perceptions of balance function should be considered in the discharge planning process when making decisions about postacute care for this population.

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REFERENCES

1. Kiekens C, Boldrini P, Andreoli A, et al. Rehabilitation and respiratory management in the acute and early post-acute phase. "Instant paper from the field" on rehabilitation answers to the COVID-19 emergency. *Eur J Phys Rehabil Med.* 2020;56(3):323-326.
2. Roberts CM, Levi M, McKee M, Schilling R, Lim WS, Grocott MPW. COVID-19: A complex multisystem disorder. *Br J Anaesth.* 2020;125(3): 238-242.
3. Lai C-C, Ko W-C, Lee P-I, Jean S-S, Hsueh P-R. Extra-respiratory manifestations of COVID-19. *Int J Antimicrob Agents.* 2020;56(2): 106024.
4. Tsai P-H, Lai W-Y, Lin Y-Y, et al. Clinical manifestation and disease progression in COVID-19 infection. *J Chin Med Assoc.* 2021;84(1):3-8.
5. Soares MN, Eggelbusch M, Naddaf E, et al. Skeletal muscle alterations in patients with acute Covid-19 and post-acute sequelae of Covid-19. *J Cachexia Sarcopenia Muscle.* 2022;13(1):11-22.
6. Pires RE, Reis IGN, Waldolato GS, Pires DD, Bidolegui F, Giordano V. What do we need to know about musculoskeletal manifestations of COVID-19?: A systematic review. *JBJS Rev.* 2022;10(6):e22.00013.
7. Carod-Artal FJ. Neurological complications of coronavirus and COVID-19. *Rev Neurol.* 2020;70(9):311-322.
8. Vitalakumar D, Sharma A, Kumar A, Flora SJS. Neurological manifestations in COVID-19 patients: A meta-analysis. *ACS Chem Neurosci.* 2021;12(15):2776-2797.
9. Fiani B, Covarrubias C, Desai A, Sekhon M, Jarrah R. A contemporary review of neurological sequelae of COVID-19. *Front Neurol.* 2020;11: 640.
10. Mao L, Jin H, Wang M, et al. Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China. *JAMA Neurol.* 2020;77(6):683-689.
11. Vacchiano V, Riguzzi P, Volpi L, et al. Early neurological manifestations of hospitalized COVID-19 patients. *Neurol Sci.* 2020;41(8):2029-2031.
12. Whittaker A, Anson M, Harky A. Neurological manifestations of COVID-19: A systematic review and current update. *Acta Neurol Scand.* 2020;142(1):14-22.

13. Correia AO, Feitosa PWG, Moreira JLdS, Nogueira SÁR, Fonseca RB, Nobre MEP. Neurological manifestations of COVID-19 and other coronaviruses: A systematic review. *Neurol Psychiatry Brain Res*. 2020; 37:27-32.
14. Nashner LM, Shupert CL, Horak FB, Black FO. Organization of posture controls: An analysis of sensory and mechanical constraints. *Prog Brain Res*. 1989;80:411-418; discussion 395–397.
15. Lima TRL, Guimarães FS, Sá Ferreira A, Penafortes JTS, Almeida VP, Lopes AJ. Correlation between posture, balance control, and peripheral muscle function in adults with cystic fibrosis. *Physiother Theor Pract*. 2014;30(2):79-84.
16. Penafortes JTS, Guimarães FS, Moço VJR, Almeida VP, Menezes SLS, Lopes AJ. Relationship between body balance, lung function, nutritional status and functional capacity in adults with cystic fibrosis. *Braz J Phys Ther*. 2013;17(5):450-457.
17. Lopez AD, Shibuya K, Rao C, et al. Chronic obstructive pulmonary disease: Current burden and future projections. *Eur Respir J*. 2006;27(2): 397-412.
18. Agustí AG, Noguera A, Sauleda J, Sala E, Pons J, Busquets X. Systemic effects of chronic obstructive pulmonary disease. *Eur Respir J*. 2003; 21(2):347-60.
19. Hellström K, Vahlberg B, Urell C, Emtner M. Fear of falling, fall-related self-efficacy, anxiety and depression in individuals with chronic obstructive pulmonary disease. *Clin Rehabil*. 2009;23(12):1136-1144.
20. Zago M, Sforza C, Bonardi DR, Guffanti EE, Galli M. Gait analysis in patients with chronic obstructive pulmonary disease: A systematic review. *Gait Posture*. 2018;61:408-415.
21. Chung JH, Kim TH, Han CH. Association between asthma and falls: A nationwide population-based study. *J Asthma*. 2018;55(7):734-740.
22. Ludwig S, Schell A, Berkemann M, et al. Post-COVID-19 impairment of the senses of smell, taste, hearing, and balance. *Viruses*. 2022;14(5):849.
23. Yılmaz O, Mutlu BÖ, Yaman H, Bayazıt D, Demirhan H, Bayazıt YA. Assessment of balance after recovery from Covid-19 disease. *Auris Nasus Larynx*. 2022;49(2):291-298.
24. Viola P, Ralli M, Pisani D, et al. Tinnitus and equilibrium disorders in COVID-19 patients: Preliminary results. *Eur Arch Otorhinolaryngol*. 2021;278(10):3725-3730.
25. Özçelik Korkmaz M, Eğilmez OK, Özçelik MA, Güven M. Otolaryngological manifestations of hospitalised patients with confirmed COVID-19 infection. *Eur Arch Otorhinolaryngol*. 2021; 278(5):1675-1685.
26. Almufarrij I, Munro KJ. One year on: An updated systematic review of SARS-CoV-2, COVID-19 and audio-vestibular symptoms. *Int J Audiol*. 2021;60(12):935-945.
27. Almufarrij I, Uus K, Munro KJ. Does coronavirus affect the audio-vestibular system? A rapid systematic review. *Int J Audiol*. 2020;59(7): 487-491.
28. Malayala SV, Raza A. A case of COVID-19-induced vestibular neuritis. *Cureus*. 2020;12(6):e8918.
29. Al Haddad MA, John M, Hussain S, Bolton CE. Role of the timed up and go test in patients with chronic obstructive pulmonary disease. *J Cardiopulmonary Rehabil Prev*. 2016;36(1):49-55.
30. Beauchamp MK, Sibley KM, Lakhani B, et al. Impairments in systems underlying control of balance in COPD. *Chest*. 2012;141(6):1496-1503.
31. Panel on Prevention of Falls in Older Persons American Geriatrics Society and British Geriatrics Society. Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. *J Am Geriatr Soc*. 2011; 59(1):148-57.
32. World Health Organization. *Clinical Management of COVID-19: Living Guideline, 13 January 2023*. Geneva: World Health Organization; 2023.
33. Prevention CDCa. *Ending Isolation and Precautions for People with COVID-19: Interim Guidance*, 2022. https://www.cdc.gov/coronavirus/2019-ncov/hcp/duration-isolation.html#:~:text=Isolation%20should%20continue%20for%20at,remain%20infectious%20beyond%2010%20days. Accessed August 2, 2023.
34. Marshall JC, Murthy S, Diaz J et al. A minimal common outcome measure set for COVID-19 clinical research. *Lancet Infect Dis*. 2020;20: e192-e197.
35. Powell LE, Myers AM. The activities-specific balance confidence (ABC) scale. *J Gerontol A Biol Sci Med Sci*. 1995;50A(1):M28-M34.
36. Podsiadlo D, Richardson S. The timed "up & Go": A test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991; 39(2):142-148.
37. Shumway-Cook A, Horak FB. Assessing the influence of sensory interaction on balance. *Phys Ther*. 1986;66(10):1548-1550.
38. Hatch J, Gill-Body KM, Portney LG. Determinants of balance confidence in community-dwelling elderly people. *Phys Ther*. 2003; 83(12):1072-1079.
39. Wrisley DM, Kumar NA. Functional gait assessment: Concurrent, discriminative, and predictive validity in community-dwelling older adults. *Phys Ther*. 2010;90(5):761-773.
40. Alsalaheen BA, Mucha A, Morris LO, et al. Vestibular rehabilitation for dizziness and balance disorders after concussion. *J Neurol Phys Ther*. 2010;34(2):87-93.
41. Beauchamp MK, Brooks D, Goldstein RS. Deficits in postural control in individuals with COPD—emerging evidence for an important secondary impairment. *Multidisciplinary Respir Med*. 2010;5(6):417-421.
42. Beauchamp MK, Hill K, Goldstein RS, Janaudis-Ferreira T, Brooks D. Impairments in balance discriminate fallers from non-fallers in COPD. *Respir Med*. 2009;103(12):1885-1891.
43. Toupet M, Ferrary E, Grayeli AB. Visual analog scale to assess vertigo and dizziness after repositioning maneuvers for benign paroxysmal positional vertigo. *J Vestib Res*. 2011;21(4):235-241.
44. Alfonso-Rosa RM, Del Pozo-Cruz B, Del Pozo-Cruz J, Sañudo B, Rogers ME. Test-retest reliability and minimal detectable change scores for fitness assessment in older adults with type 2 diabetes. *Rehabil Nurs*. 2014;39(5):260-268.
45. Criter RE, Honaker JA. Identifying balance measures most likely to identify recent falls. *J Geriatr Phys Ther*. 2016;39(1):30-37.
46. Dal Bello-Haas V, Klassen L, Sheppard MS, Metcalfe A. Psychometric properties of activity, self-efficacy, and quality-of-life measures in individuals with Parkinson disease. *Physiother Can*. 2011;63(1):47-57.
47. Marques A, Cruz J, Quina S, Regêncio M, Jácome C. Reliability, agreement and minimal detectable change of the timed up & go and the 10-meter walk tests in older patients with COPD. *COPD*. 2016;13(3):279-287.
48. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. *Phys Ther*. 2000;80(9):896-903.
49. McLay R, Kirkwood RN, Kuspinar A, et al. Validity of balance and mobility screening tests for assessing fall risk in COPD. *Chron Respir Dis*. 2020;17:147997312092253.
50. Trueblood P, Hodson-Chennault N, McCubbin A, Youngclarke D. Performance and impairment-based assessments among community dwelling elderly: Sensitivity and specificity. *J Geriatr Phys Ther*. 2001; 24(1):2-6.
51. O'Brien MK, Hidalgo-Araya MD, Mummidisetty CK, et al. Augmenting clinical outcome measures of gait and balance with a single inertial sensor in age-ranged healthy adults. *Sensors (Basel)*. 2019;19(20):4537.
52. Cohen H, Blatchly CA, Gombash LL. A study of the clinical test of sensory interaction and balance. *Phys Ther*. 1993;73(6):346-51; discussion 351–354.
53 Bascuas I, Tejero M, Monleón S, Boza R, Muniesa JM, Belmonte R. Balance 1 year after TKA: Correlation with clinical variables. *Orthopedics*. 2013;36(1):e6-e12.
54. Loughran S, Tennant N, Kishore A, Swan IR. Interobserver reliability in evaluating postural stability between clinicians and posturography. *Clin Otolaryngol*. 2005;30(3):255-257.
55. Pagnacco G, Carrick FR, Wright CH, Oggero E. Between-subjects differences of within-subject variability in repeated balance measures: Consequences on the minimum detectable change. *Gait Posture*. 2015; 41(1):136-140.
56. Park MK, Kim KM, Jung J, Lee N, Hwang SJ, Chae SW. Evaluation of uncompensated unilateral vestibulopathy using the modified clinical test for sensory interaction and balance. *Otol Neurotol*. 2013;34(2):292-296.
57. Weirich G, Bemben DA, Bemben MG. Predictors of balance in young, middle-aged, and late middle-aged women. *J Geriatr Phys Ther*. 2010; 33(3):110-117.

58. Whitney SL, Marchetti GF, Ellis JL, Otis L. Improvements in balance in older adults engaged in a specialized home care falls prevention program. *J Geriatr Phys Ther*. 2013;36(1):3-12.
59. Nitz JC, Stock L, Khan A. Health-related predictors of falls and fractures in women over 40. *Osteoporos Int*. 2013;24(2):613-621.
60. Boonsinsukh R, Khumnonchai B, Saengsirisuwan V, Chaikeeree N. The effect of the type of foam pad used in the modified Clinical Test of Sensory Interaction and Balance (mCTSIB) on the accuracy in identifying older adults with fall history. *Hong Kong Physiother J*. 2020;40(02):133-143.
61. Eisner MD, Blanc PD, Yelin EH, et al. COPD as a systemic disease: Impact on physical functional limitations. *Am J Med*. 2008;121(9):789-796.
62. Roig M, Eng JJ, Macintyre DL, Road JD, Reid WD. Postural control is impaired in people with COPD: An observational study. *Physiother Can*. 2011;63(4):423-431.
63. Butcher SJ, Meshke JM, Sheppard MS. Reductions in functional balance, coordination, and mobility measures among patients with stable chronic obstructive pulmonary disease. *J Cardiopulmonary Rehabil*. 2004;24(4): 274-280.
64. Crişan AF, Oancea C, Timar B, Fira-Mladinescu O, Tudorache V. Balance impairment in patients with COPD. *PLoS One*. 2015;10(3):e0120573.
65. Porto EF, Castro AA, Schmidt VG, et al. Postural control in chronic obstructive pulmonary disease: A systematic review. *Int J Chron Obstruct Pulmon Dis*. 2015;10:1233-1239.
66. Vardar-Yagli N, Saglam M, Calik-Kutukcu E, Inal-Ince D, Arikan H, Coplu L. Increased pain sensitivity, postural abnormalities, and functional balance impairment in obstructive lung disease compared to healthy subjects. *Heart Lung*. 2019;48(4):351-355.
67. Chauvin S, Kirkwood R, Brooks D, Goldstein RS, Beauchamp MK. Which balance subcomponents distinguish between fallers and non-fallers in people with COPD? *Int J Chronic Obstruct Pulm Dis*. 2020;15: 1557-1564.
68. Janssens L, Brumagne S, McConnell AK, et al. Proprioceptive changes impair balance control in individuals with chronic obstructive pulmonary disease. *PLoS One*. 2013;8(3):e57949.
69. Janssens L, Brumagne S, McConnell AK, et al. Impaired postural control reduces sit-to-stand-to-sit performance in individuals with chronic obstructive pulmonary disease. *PLoS One*. 2014;9(2):e88247.
70. Kaygusuz MH, Oral Tapan O, Tapan U, Genc S. Balance impairment and cognitive dysfunction in patients with chronic obstructive pulmonary disease under 65 years. *Clin Respir J*. 2022;16(3): 200-207.
71. Saniasiaya J, Kulasegarah J. Dizziness and COVID-19. *Ear Nose Throat J*. 2021;100:29-30.
72. Hill K, Goldstein RS. Limited functional performance in chronic obstructive pulmonary disease: Nature, causes and measurement. *COPD*. 2007;4(3):257-261.
73. Smith MD, Chang AT, Seale HE, Walsh JR, Hodges PW. Balance is impaired in people with chronic obstructive pulmonary disease. *Gait Posture*. 2010;31(4):456-460.
74. Boffino CC, Pereira ACAC, Coelho DB, et al. Age and disease have a distinct influence on postural balance of patients with COPD. *COPD*. 2019;16(3-4):246-253.
75. de Castro LA, Ribeiro LR, Mesquita R, et al. Static and functional balance in individuals with COPD: Comparison with healthy controls and differences according to sex and disease severity. *Respir Care*. 2016; 61(11):1488-1496.
76. Riandini T, Khoo EYH, Tai BC, et al. Fall risk and balance confidence in patients with diabetic peripheral neuropathy: An observational study. *Front Endocrinol (Lausanne)*. 2020;11:573804.