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REVIEW ARTICLE (META-ANALYSIS)

Clinical Utility of Remote Teleassessment of Motor Performance in Individuals With Neurologic Disabilities: A COSMIN Systematic Review

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Abstract

Objective: To investigate the feasibility and measurement properties of measurement tools for remote evaluation of motor performance in people with neurologic conditions requiring only synchronous or asynchronous video conferencing without sensors or other complex technological tools.

Data Sources: A systematic search was conducted in PubMed, Embase, the Cumulative Index for Nursing and Allied Health Literature (CINHAL), and ScienceDirect. The search strategy included keywords related to any neurologic population, telerehabilitation, and motor performance outcome measure; papers in Italian or English language on adults were included, without time restrictions.

Study Selection: We included studies reporting data of at least one measurement property between reliability, validity, feasibility, or acceptability of measurement tools for remote motor assessment in neurologic disorders. We excluded studies that used wearable technologies, smartphones, or mobile applications. After duplicate removal, 2530 records were screened. Of the 461 remaining papers, 26 met the inclusion criteria and were included in the systematic review.

Data Extraction: Two independent reviewers extracted data from the included records, evaluated the risk of bias of the studies using the Consensus-based Standards for the selection of health Measurement Instruments tool, and applied the criteria for good measurement properties and clinical utility. Discordance was solved through discussion with a third reviewer.

Data Synthesis: Twenty-nine measurement tools were identified, and a narrative synthesis was conducted because of the heterogeneity of the included studies. The Fugl-Meyer Assessment for the Lower and Upper Extremity and the Tinetti Performance-Oriented Mobility Assessment Balance were suggested for the remote evaluation of people with stroke, whereas the Five Times Sit-to-Stand Test, the Nine-Hole Peg Test, and the Timed 25-Foot Walk Test were suggested for people with multiple sclerosis.

Conclusions: Several measurement tools have been identified for remote evaluation of motor performance in people with neurologic disorders, but few of them can be suggested for clinical and scientific purposes. A higher methodological quality of studies would support the use of these tools in clinical practice.

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Neurologic disorders affect more than 3 billion people worldwide, accounting for 11.1 million deaths and 443 million disability-adjusted life years.[1] These conditions represent one of the main contributors to global disability-adjusted life years because of

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increased life expectancy and improved acute management, resulting in an increase in the population living with long-term disabilities.[1] Among neurologic disorders, stroke, Parkinson disease (PD), traumatic brain injury, spinal cord injury (SCI), and multiple sclerosis (MS) significantly contribute to this burden because of their associated motor impairments.[1] This growing prevalence underscores the need for careful planning of health resources to cope with the increasing number of people living with long-term disabilities and to ensure adequate financial and personnel resources for rehabilitation services.[2] The recent COVID-19 pandemic particularly emphasized the strain on the national health system, highlighting critical access to care for people with neurologic disorders, particularly for rehabilitation.[3] To address the increasing demand for medical services, innovative approaches such as telemedicine need to be implemented to meet the needs of people with motor impairment and support national health systems.[4]

Telerehabilitation is one of the branches of telemedicine and delivers rehabilitation services using various information and communication technologies (ICT). Telerehabilitation includes the assessment, monitoring, prevention, intervention, education, consultation, and coaching of patients through technological solutions ranging from chat messaging to home virtual reality.[5]

People with chronic neurologic disorders can be particularly assisted by telerehabilitation, meeting their need for frequent medical evaluations and rehabilitative treatments.[6] Several barriers restrict the possibility for these individuals to have easy access to care, including transportation difficulties and a lack of specialized rehabilitation services,[7] particularly in low- and middle-income countries and rural areas.[8,9] The implementation of telerehabilitation is now helping to overcome these barriers and propose specialized services through ICT.[10]

However, most research in telerehabilitation focused on rehabilitation treatment, whereas less information is available on remote assessment.[10] Therefore, it is essential to provide an overview of the feasibility and quality of the measurement tools available for evaluating people with neurologic disorders to support the clinician's decision-making process.

A preliminary synthesis of primary research has already been conducted on this topic.[11] However, to the best of our knowledge, no systematic reviews have focused exclusively on clinician reported and performance-based outcome measurement instruments.[12]

Therefore, this systematic review aimed to assess the feasibility and measurement properties of remote assessment of motor performance in people with neurologic conditions that do not require wearable technologies, mobile applications, or robotic devices. The reason for excluding more complex technological solutions is to provide a comprehensive overview of the quality of teleassessment tools that could be used by all clinicians and researchers, including those with less access to expensive ICT solutions.

List of abbreviations:

5TSST	**Five Times Sit-to-Stand Test**
9HPT	**Nine-Hole Peg Test**
FMA	**Fugl-Meyer Assessment**
FMA-LE	**Fugl-Meyer Assessment—Lower Extremity**
FMA-UE	**Fugl-Meyer Assessment—Upper extremity**
ICT	**information and communication technologies**
MS	**multiple sclerosis**
OMI	**outcome measurement instruments**
PD	**Parkinson disease**
POMA-B	**Performance-Oriented Mobility Assessment Balance**
SCI	**spinal cord injury**
T25FWT	**Timed 25-Foot Walk Test**

Methods

In this systematic review, the guidelines for reporting a systematic review of outcome measurement instruments (PRISMA-COSMIN for OMIs 2024) were used[13] (supplemental appendix S1, available online only at http://www.archives-pmr.org/, for the detailed PRISMA-COSMIN for OMIs Checklist).

Eligibility criteria

We included all studies reporting the use of remote outcome measurement instruments for motor performance in adults (>18 y) with neurologic conditions, such as, but not limited to, stroke, MS, PD, traumatic brain injury, and SCI. We considered observational and interventional trials published in the Italian or English language that met the following inclusion criteria: (1) the presence of at least one measurement property between reliability, validity, feasibility, or acceptability; and (2) evaluation of motor performance remotely in synchronous (video conference) or asynchronous (videorecording) modality by a clinician. The exclusion criteria were as follows: (1) studies reporting the use of outcome measurement instruments for remotely evaluating motor performance using wearable technologies, smartphones (except for capturing photos, videos, or video conferences), mobile applications, and robotic devices; and (2) studies evaluating only patient-reported outcomes.

Information sources

The literature search was performed in the following electronic databases: PubMed, Embase, the Cumulative Index for Nursing and Allied Health Literature (CINAHL), and ScienceDirect. The database search was completed on April 2, 2024, and was frequently updated until October 2, 2024; no temporal restrictions were applied retrospectively.

Search strategy

The PIO (Patient, Intervention, Outcome) framework was used to define the search question, and the search strategy included vocabulary and keywords related to any neurologic population, telerehabilitation, and motor performance outcome measure. The comprehensive database search strategy is available in the supplemental appendix S2 (available online only at http://www.archives-pmr.org/). The gray literature was screened using the search string "remote assessment" AND "neurologic disorder" on Google.

Selection process

Articles retrieved from the electronic search were imported into the Rayyan web app[a] (https://rayyan.ai/) for systematic reviews,[14] and duplicates were excluded. Two independent reviewers (A.A., G.F.) screened titles and abstracts, and disagreements were solved by a third reviewer (S.S.). The full texts of potentially eligible studies were retrieved and independently assessed for eligibility by A.A. and G.F.; any discordance between them was resolved

through discussion with a third reviewer (S.S.). If the data could not be extracted from the selected reports, the authors were contacted twice within 2 weeks to request the necessary data.

Data collection process

Two reviewers (A.C., G.P.) independently extracted data using a predefined electronic spreadsheet. Discrepancies between them were resolved by a third reviewer (A.B.).

Data items

The following data were extracted from each included study: author(s), year of publication, study design, characteristics of participants (demographic, clinical details), outcome measure(s), modalities of administration, measurement properties under investigation, and information on feasibility (completion time, ease of administration, cost).

Study risk of bias assessment

The Consensus-based Standards for the selection of health Measurement Instruments (COSMIN), Risk of Bias tool for Patient−Reported Outcome Measures,[15-17] and the COSMIN Risk of Bias tool to assess the quality of studies on reliability and measurement error[12] were used for the assessment of the methodological quality of the included studies. The COSMIN tool consists of 10 boxes, but only the last 5 apply to studies on motor performance and evaluate reliability, measurement error, criterion validity, hypothesis testing for construct validity, and responsiveness. Each box can be scored on a 4−point scale (“very good,” “adequate,” “doubtful,” and “inadequate”). The "worst score counts" principle was used, where the overall rating for each measurement property is given by the lowest rating of any standard in the box.[12] Two independent evaluators performed the assessments (A.C. and G.P.), and disagreements were discussed with a third evaluator (A.B.). All the evaluators involved in the quality assessment had previous experience in the use of the COSMIN tool.

Measurement properties assessment

The criteria developed by Terwee et al[18] for good measurement properties were applied to each result. A total quality score is calculated considering the lowest score obtained in each box (worst−score−counts method) and can be evaluated as “sufficient,” “insufficient,” or “indeterminate.” Two reviewers (A.C., G.P.) independently performed each step of the quality evaluation. Discrepancies were resolved by discussion and/or consultation with a third reviewer (A.B.).

Clinical utility assessment

The Tyson and Connell scale was used to assess the clinical utility of the measurement tools.[19] Each measurement tool can reach a score of 0-10 on the basis of the application time (0-3 points), cost (0-3 points), need for specialized equipment/training (0-2 points), and portability and accessibility (0-2 points). Two independent evaluators (A.A., G.F.) performed the assessments, and disagreements were discussed with a third evaluator (A.B.).

Synthesis methods

Because of the heterogeneity of the included studies in terms of population and outcome measurement tools, a narrative synthesis was conducted in line with the narrative synthesis in systematic reviews recommendation.[20]

Formulating suggestions for current practice

The measurement tools suggested for their use in current practice were selected on the basis of the methodological quality of the study, the quality of the measurement property, and the clinical utility of the tool. The following criteria were used: (1) methodological quality of the study rated as “adequate” or “very good,”[12] (2) quality of the measurement property is rated as “sufficient,”[18] and (3) clinical utility on the Tyson and Connell scale ≥8.[19]

Results

Study selection

The database search identified 2699 records. After removing duplicates, 2530 titles and abstracts were screened, and 2069 were excluded. Among the 461 remaining papers, 435 did not meet the inclusion criteria and were excluded from the collection. Specifically, of the excluded papers, 214 applied a different type of intervention, 133 recorded a different outcome, 57 had a study design different from an observational and interventional trial, 26 remotely evaluated different populations (ie, <18 y), and 5 were written in languages different from Italian or English. Twenty-six papers were included in this systematic review. A flow diagram of the selection process is available in figure 1. A total of 29 measurement tools involving 739 people with neurologic disorders were identified: 13 for people with PD (266 subjects in 12 studies),[21-32] 8 for people with stroke (246 subjects in 9 studies),[10,33-40] 2 for people with SCI (94 subjects in 2 studies),[41,42] and 6 for people with MS (133 subjects in 3 studies).[43-45] Five of the included measurement tools were available for different neurologic populations.[10,21,24,25,28,32,34,37,43-45] Fifteen clinician reported outcomes[10,22,23,25-36,38-40,42,44] and 14 performance-based outcomes[21,23-25,28,32,35,37,41,43-45] were assessed in the included studies. A detailed description of the included studies is reported in table 1.

Assessment of the methodological quality

Eight studies were excluded from the methodological quality assessment because they evaluated only the feasibility of remote evaluation[21,22,26,29,31,32] or did not report extractable data.[37,38]

The methodological quality of the included studies ranged from “very good” to “inadequate” following the COSMIN criteria (fig 2). Reliability was evaluated in 16 studies[10,23-25,27,28,30,34-36,39,40,42-45]: 1 was classified as very good,[45] 3 as adequate,[30,40,43] 1 as doubtful,[36] and 11 as inadequate.[10,23-25,27,28,34,35,39,42,44] The measurement error was investigated in 14 studies[10,24,25,27,28,32-36,40,42-44]: 1 was classified as very good,[43] 1 as adequate,[40] 1 as doubtful,[36] and 11 as inadequate.[10,24,25,27,28,32-35,42,44] Four studies investigated construct validity[35,36,40,41]: 3 were classified as very good[35,40,41] and 1 was classified as adequate.[36] Seven studies investigated criterion validity[25,32,33,35,36,39,42]: 1 was classified as

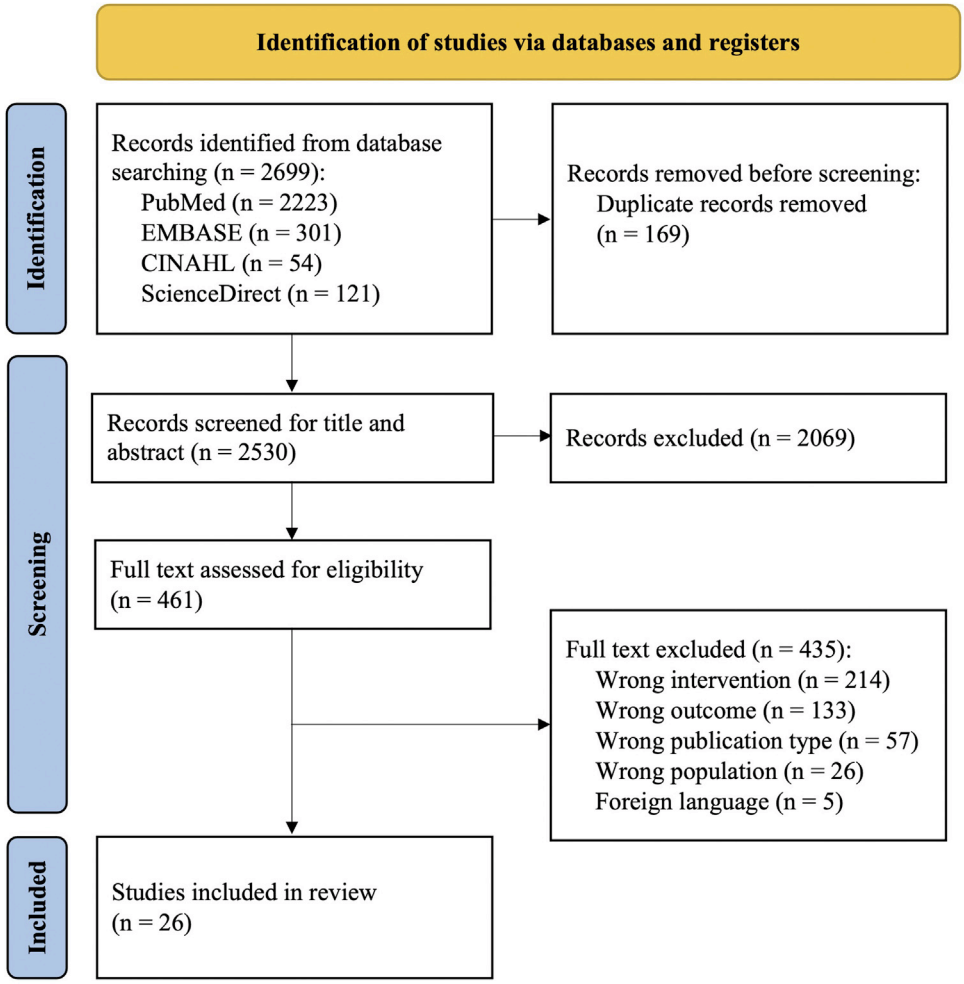

Fig 1 PRISMA 2020 flow diagram of the systematic review.

very good,[36] 2 were classified as doubtful,[33,35] and 4 were classified as inadequate.[25,32,39,42] None of the included studies evaluated the internal consistency, content validity, or responsiveness of the measurement tool identified for the remote assessment.

Assessment of the measurement properties

Reliability was rated as sufficient for 24 measurement tools,[10,23-25,28,34-36,40,42-45] indeterminate for 1 tool,[39] and insufficient for 2 tools.[27,30] The measurement error was rated as sufficient for 6 measurement tools,[10,28,35] indeterminate for 13 tools,[10,24,25,27,32,34,36,40,42-44] and insufficient for 5 tools.[10,25,28,33,44] The construct validity was evaluated for 5 measurement tools and was rated as sufficient for 3 of them[35,40] and insufficient for 2.[36,41] Criterion validity was rated as sufficient for 6 measurement tools,[32,33,35,36,42] indeterminate for 2 tools,[25,39] and insufficient for 1 tool.[35] The results for all the measurement properties for each study are reported in figure 2 and the supplemental appendix S3 (available online only at http://www.archives-pmr.org/).

Assessment of the clinical utility

A total of 22 measurement tools were evaluated for clinical utility,[10,21-45] 3 of them in different versions,[10,22,25-27,29-33,35,38,39] (table 2). The overall clinical utility ranged from 7 to 10. Ten measurement tools scored 10,[10,21,23,24,28,32,41,43,44] 6 scored 9,[10,27,35-38,44,45] (including a reduced version of the Movement Disorders Society-Unified Parkinson Disease Rating Scale (MDS-UPDRS) that uses only 3 items of the full scale[27]), 3 scored 8,[10,22,25,26,28-32,34,44,45] and 3 scored 7.[33,35,39,40,42]

Suggested measurement tools

Seven measurement tools showed ≥1 measurement property rated as "sufficient" in a study, with the methodological quality classified as "very good" or "adequate."[35,36,40,43,45] The measurement property that most met these criteria was reliability.[40,43,45]

Nineteen measurement tools scored ≥8 on the clinical utility assessment and were considered feasible for use in clinical practice.[10,21-32,34-38,41,43-45] Considering the methodological quality of the studies, the quality of the measurement properties and the clinical utility of the tools, 6 measurement tools were suggested for the remote evaluation of motor performance in neurologic disorders: Fugl-Meyer Assessment for the Lower and Upper Extremity (FMA-LE, FMA-UE)[35] and Tinetti Performance-Oriented Mobility Assessment Balance (POMA-B)[36] for people with stroke; and Five Times Sit-to-Stand Test (5TSST),[43] Nine-Hole Peg Test (9HPT), and Timed 25-Foot Walk Test (T25FWT)[45] for people with MS.

Table 1 Characteristics of the included studies.

Measurement Tool	Domain	Author Group	Y	Population	Sample Size	Sample Characteristics	Type of Outcome	Modalities
ArmCAM	Upper limb function	Yang et al[40]	2023	Stroke	31	Sex: 11 females Mean age: 64.0 (12.0) y of this: 10 (FMA-UE and ARAT, 4F, 58±12 y)	ClinROM	Synchronous Support allowed (caregiver)
BBS	Balance	Gillespie et al[34]	2021	Stroke	20	Sex: 9 females Mean age: 72.0 (9.4) y	ClinROM	Synchronous Support present (clinician)
		Zhang et al[10]	2024	Stroke	60	Sex: 17 females Mean age: 55.6 (14.1) y	ClinROM	Synchronous Support present (caregiver) Testing equipment provided (manual)
		Russell et al[28]	2013	PD	12	Sex: 6 females Mean age: 66.1 (8.5) y	ClinROM	Synchronous/asynchronous Support present (clinician)
		Erekdag et al[44]	2024	MS	39	Sex: 26 females Mean age: 37.8 (11.6) y	ClinROM	Synchronous Support present (clinician) Testing equipment provided (manual)
CRT	Hand function	Cabrera-Martos et al[23]	2019	PD	21	Sex: 9 females Mean age: 70.9 (9.6) y	PerFOM	Synchronous
DGI	Balance	Erekdag et al[44]	2024	MS	39	Sex: 26 females Mean age: 37.8 (11.6) y	ClinROM	Synchronous Support present (clinician) Testing equipment provided (manual)
FMA-LE (without the reflex items)	Lower limb function	Liz et al[35]	2023	Stroke	45	11 people for in-person evaluation Sex: 1 female Mean age: 66.0 (12.0) y 34 people for remote evaluation Sex: 9 female Mean age: 61.0 (14.0) y	ClinROM	Synchronous/asynchronous Support allowed (caregiver) Testing equipment provided (manual)
		Zhang et al[10]	2024	Stroke	60	Sex: 17 females Mean age: 55.6 (14.1) y	ClinROM	Synchronous Support present (caregiver) Testing equipment provided (manual)
FMA-LE (modified version)	Lower limb function	Peters et al[38]	2021	Stroke	5	Sex: 1 female Mean age: 63.0 (5.7) y	ClinROM	Synchronous Testing equipment provided (manual, kit)

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Table 1 (*Continued*)

Measurement Tool	Domain	Author Group	Y	Population	Sample Size	Sample Characteristics	Type of Outcome	Modalities
FMA-UE (without the reflex items, wrist, and coordination/speed subscales)	Upper limb function	Carmona et al[33]	2023	Stroke	22	Sex: 5 females Mean age: 61.5 (9.27) y	ClinROM	Synchronous
FMA-UE (without the reflex items)	Upper limb function	Liz et al[35]	2023	Stroke	45	11 people for in-person evaluation Sex: 1 female Mean age: 66.0 (12.0) y 34 people for remote evaluation Sex: 9 female Mean age: 61.0 (14.0) y	ClinROM	Synchronous/asynchronous Support allowed (caregiver) Testing equipment provided (manual)
		Rowe et al[39]	2023	Stroke	12	-	ClinROM	Synchronous Support present (caregiver) Testing equipment provided (manual, kit)
FRT	Balance	Palsbo et al[37]	2007	Stroke	26	Sex: 8 females Median age: 64.0 y (Min-Max, 25.0-81.0 y)	PerFOM	Synchronous Support present (clinician)
5TSST	Lower limb strength	Afshari et al[21]	2022	PD	15	Sex: 5 females Median age: 67.0 y (IQR, 64.0-73.0 y)	PerFOM	Synchronous Support present (caregiver)
		Figueiredo et al[24]	2024	PD	12	Sex: 10 females Mean age: 69.0 y (CI, 65.1-72.8 y)	PerFOM	Synchronous Support present (caregiver)
		Dos Santos et al[43]	2023	MS	33	Sex: 18 females Mean age: 43.7 (13.4) y	PerFOM	Synchronous
FTT	Coordination	Cabrera-Martos et al[23]	2019	PD	21	Sex: 9 females Mean age: 70.9 (9.6) y	PerFOM	Synchronous
GRASSP (modified version)	Hand function	Voss et al[42]	2023	SCI	61	Sex: 18 females Mean age: 49.0 (15.0) y	ClinROM	Synchronous/asynchronous Support present (caregiver)
MDS-UPDRS (14 selected items)	Gait function, tremor, balance	Hoffmann et al[25]	2008	PD	12	Sex: 6 females Mean age: 66.1 (8.5) y	ClinROM	Synchronous Support present (caregiver)

(*continued on next page*)

Table 1 (*Continued*)

Measurement Tool	Domain	Author Group	Y	Population	Sample Size	Sample Characteristics	Type of Outcome	Modalities
MDS-UPDRS (without rigidity and postural instability test)	Mentation, behavior, mood, ADL, motor function, drug effects	Tarolli et al[30]	2020	PD	40	Sex: 11 females Mean age: 64.3 (10.4) y	ClinROM	Synchronous
		Leòn-Garcìa et al[26]	2023	PD	24	Sex: 12 females Mean age: 69.96 (6.61) y	ClinROM	Synchronous Support present (caregiver)
		Stillerova et al[29]	2016	PD	11	Sex: 4 females Median age: 69.0 y (IQR, 57.0-76.0 y)	ClinROM	Synchronous
		Teixeira-Dos-Santos et al[31]	2023	PD	34	Sex: 16 females Mean age: 65.8 (11.8) y	ClinROM	Synchronous Support allowed (caregiver)
		Virmani et al[32]	2022	PD	50	26 people for in-person evaluation Sex: 30 females Mean age: 65.8 (9.2) y	ClinROM	Synchronous Testing equipment provided (manual)
MDS-UPDRS I-III (without rigidity and postural instability test)	Mentation, behavior, mood, ADL, motor function	Bianchini et al[22]	2022	PD	23	Sex: 10 females Mean age: 64.1 (8.9) y	ClinROM	Synchronous Support allowed (caregiver)
MDS-UPDRS III (items 3.4, 3.5, 3.6)	Hand function, finger dexterity, ataxia	Luiz et al[27]	2021	PD	12	Sex: 4 females Mean age: 69.0 (7.5) y	ClinROM	Asynchronous
9HPT	Manual dexterity	Hoffmann et al[25]	2008	PD	12	Sex: 6 females Mean age: 66.1 (8.5) y	PerFOM	Synchronous Support present (clinician)
		Van Denend et al[45]	2024	MS	61	Sex: 48 females Mean age: 52.3 (11.4) y	PerFOM	Synchronous/asynchronous Support allowed (caregiver) Testing equipment provided (manual, kit)
Push-up test	Upper limb function	Gomes Costa et al[41]	2024	SCI	33	Sex: 8 females Mean age: 35.5 (9.8) y	PerFOM	Synchronous/asynchronous
RTT	Balance	Afshari et al[21]	2022	PD	15	Sex: 5 females Median age: 67.0 y (IQR, 64.0-73.0 y)	PerFOM	Synchronous Support present (caregiver)

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Table 1 (*Continued*)

Measurement Tool	Domain	Author Group	Y	Population	Sample Size	Sample Characteristics	Type of Outcome	Modalities
Step test	Balance	Liz et al[35]	2023	Stroke	45	11 people for in-person evaluation Sex: 1 female Mean age: 66.0 (12.0) y 34 people for remote evaluation Sex: 9 female Mean age: 61.0 (14.0) y	PerFOM	Synchronous/asynchronous Support allowed (caregiver) Testing equipment provided (manual)
T25FWT	Gait function	Van Denend et al[45]	2024	MS	34	Sex: 48 females* Mean age: 52.3 (11.4)y*	PerFOM	Synchronous/asynchronous Support allowed (caregiver) Testing equipment provided (manual, kit)
Tinetti-POMA-B	Balance	Önal et al[36]	2024	Stroke	25	Sex: 8 females Mean age: 55.4 (8.4) y	ClinROM	Synchronous/asynchronous Support present (caregiver)
Tinetti-POMA-G	Gait function	Zhang et al[10]	2024	Stroke	60	Sex: 17 females Mean age: 55.6 (14.1) y	ClinROM	Synchronous Support allowed (caregiver) Testing equipment provided (manual)
Timed Stance test	Balance	Russell et al[28]	2013	PD	12	Sex: 6 females Mean age: 66.1 (8.5) y	PerFOM	Synchronous/asynchronous Support present (clinician)
TRS	Tremor	Cabrera-Martos et al[23]	2019	PD	21	Sex: 9 females Mean age: 70.9 (9.6) y	ClinROM	Synchronous
TUG	Mobility	Russell et al[28]	2013	PD	12	Sex: 6 females Mean age: 66.1 (8.5) y	PerFOM	Synchronous/asynchronous Support present (clinician)
		Virmani et al[32]	2022	PD	50	26 people for in-person evaluation Sex: 30 females Mean age: 65.8 (9.2) y	PerFOM	Synchronous Testing equipment provided (manual, kit)
		Erekdag et al[44]	2024	MS	39	Sex: 26 females Mean age: 37.8 (11.6) y	PerFOM	Synchronous Testing equipment provided (manual)

Abbreviations: 360˚ RTT, Rapid-Turns-Test; 5TSST, Five Times Sit-to-Stand Test; 9HPT, Nine-Hole Peg Test; ArmCAM, Arm Capacity and Movement Test; BBS, Berg Balance Scale; ClinROM, Clinician Reported Outcome; CRT, Coin Rotation Test; DGI, Dynamic Gait Index; F, female; FMA-LE, Fugl-Meyer Assessment—lower extremity subscale; FMA-UE, Fugl-Meyer Assessment—upper extremity subscale; FRT, Functional Reach Test; FTT, Finger Tapping Test; GRASSP, Graded Redefined Assessment of Strength, Sensation, and Prehension; IQR, interquartile range; MDC, minimal detectable change; MDS-UPDRS, Movement Disorder Society—Unified Parkinson Disease Rating Scale; MS, multiple sclerosis; ND, neurologic disorders; PD, Parkinson disease; PerFOM, performance-based outcome; SCI, spinal cord injury; T25FWT, Timed 25-Foot Walk Test; Tinetti-POMA-B, Tinetti Performance-Oriented Mobility Assessment—Balance subscale; Tinetti-POMA-G, Tinetti Performance-Oriented Mobility Assessment - Gait subscale; TRS, Tremor Rating Scale; TUG, timed Up and Go Test; y, years.

* Data related to the entire sample.

Measurement tool	Population	Measurements properties							
		Reliability			Validity				
						Construct validity			
		Internal consistency	Reliability	Measurement error	Content validity	Structural validity	Convergent validity	Criterion validity	Responsiveness
ArmCAM[40]	Stroke	-	Sufficient	Indeterminate	-	-	Sufficient	-	-
BBS[34]	Stroke	-	Sufficient	Indeterminate	-	-	-	-	-
BBS[10]	Stroke	-	Sufficient	Insufficient	-	-	-	-	-
BBS[28]	PD	-	Sufficient	Insufficient	-	-	-	-	-
BBS[44]	MS	-	Sufficient	Insufficient	-	-	-	-	-
CRT[23]	PD	-	Sufficient	-	-	-	-	-	-
DGI[44]	MS	-	Sufficient	Indeterminate	-	-	-	-	-
FMA-LE*[35]	Stroke	-	Sufficient	Sufficient	-	-	Sufficient	Sufficient	-
FMA-LE*[10]	Stroke	-	Sufficient	Sufficient	-	-	-	-	-
FMA-UE*[33]	Stroke	-	-	Insufficient	-	-	-	Sufficient	-
FMA-UE*[35]	Stroke	-	Sufficient	Sufficient	-	-	Sufficient	Insufficient	-
FMA-UE*[39]	Stroke	-	Indeterminate	-	-	-	-	Indeterminate	-
5TSST[24]	PD	-	Sufficient	Indeterminate	-	-	-	-	-
5TSST[43]	MS	-	Sufficient	Indeterminate	-	-	-	-	-
FTT[23]	PD	-	Sufficient	-	-	-	-	-	-
GRASSP*[42]	SCI	-	Sufficient	Indeterminate	-	-	-	Sufficient	-
MDS-UPDRS*[25]	PD	-	Sufficient	Insufficient	-	-	-	Indeterminate	-
MDS-UPDRS*[30]	PD	-	Insufficient	-	-	-	-	-	-
MDS-UPDRS*[32]	PD	-	-	Indeterminate	-	-	-	Sufficient	-
MDS-UPDRS III*[27]	PD	-	Insufficient	Indeterminate	-	-	-	-	-
9HPT[25]	PD	-	Sufficient	Indeterminate	-	-	-	-	-
9HPT[45]	MS	-	Sufficient	-	-	-	-	-	-
Push-Up test[41]	SCI	-	-	-	-	-	Insufficient	-	-
Step test[35]	Stroke	-	Sufficient	Sufficient	-	-	-	-	-
T25FWT[45]	MS	-	Sufficient	-	-	-	-	-	-
Tinetti-POMA-B[36]	Stroke	-	Sufficient	Indeterminate	-	-	Insufficient	Sufficient	-
Tinetti-POMA-G[10]	Stroke	-	Sufficient	Indeterminate	-	-	-	-	-
Timed Stance test[28]	PD	-	Sufficient	Sufficient	-	-	-	-	-
TUG[28]	PD	-	Sufficient	Sufficient	-	-	-	-	-
TUG[32]	PD	-	-	Indeterminate	-	-	-	Sufficient	-
TUG[44]	MS	-	Sufficient	Indeterminate	-	-	-	-	-

Fig 2 Methodological quality and measurement property assessment. COSMIN criteria for quality assessment: green=very good, blue=adequate, yellow=doubtful, red=inadequate. Abbreviations: ArmCAM, Arm Capacity and Movement Test; BBS, Berg Balance Scale; CRT, Coin Rotation Test; DGI, Dynamic Gait Index; FTT, Finger Tapping Test; GRASSP, Graded Redefined Assessment of Strength, Sensation, and Prehension; MDS-UPDRS, Movement Disorder Society—Unified Parkinson Disease Rating Scale; Tinetti-POMA-B, Tinetti Performance-Oriented Mobility Assessment—Balance subscale; Tinetti-POMA-G, Tinetti Performance-Oriented Mobility Assessment—Gait subscale; TUG, timed Up and Go Test. *Modified version of the scale.

Discussion

Clinical remote assessment represents a valuable option for evaluating motor performance in people with neurologic disorders. To the best of our knowledge, this is the first systematic review evaluating the methodological quality and clinical utility of performance evaluation without the use of sensor-based systems or mobile/computer applications to allow clinicians to evaluate patients only through a camera or videoconferencing.

Considering people with stroke, 3 measurement tools meet the criteria of methodological quality and clinical utility: 2 for the evaluation of lower and upper limb function (FMA-LE, FMA-UE)[35] and 1 for balance assessment (Tinetti POMA-B).[36] The lower and upper extremity versions of the FMA are specific for monitoring motor recovery after a cerebrovascular accident. The possibility of evaluating motor recovery in a home setting represents a valuable option for both severe and mild people with stroke: the former can be remotely evaluated without having to move from their home, and the latter can be easily monitored during their recovery phase to identify even the smallest changes in motor function. However, both FMA-LE and FMA-UE require some adaptations for remote evaluation. First, reflex items were not assessed, as suggested by previous studies showing that reflex testing did not contribute to the FMA-UE score.[46,47] Second, the caregiver was guided on how to provide resistance for the wrist items that required it. Finally, no manual resistance was provided for the item measuring extensor synergy on the FMA-LE; the item was scored as 0 or 2 only according to whether the movement was carried out or not. All these adaptations, including ad hoc camera position to permit evaluation of limb movements, were properly communicated to the caregiver to assist in the evaluation. These findings highlight the feasibility of using adapted versions of these measurement tools for remote evaluation, ensuring reliable monitoring of motor recovery in people with stroke while reducing the burden of in-person assessments, particularly for individuals with limited mobility.

In addition to motor deficits in the upper or lower limbs, people with stroke frequently experience balance impairments. These issues arise not only as a direct consequence of the cerebrovascular event but also because of common comorbidities in this population, especially among older people in the chronic stroke timeframe.[48] Such balance difficulties can significantly hinder mobility, making home-based assessments an invaluable approach to minimizing risks and alleviating discomfort for these patients. Balance can be remotely evaluated in people with stroke using the Tinetti POMA-B. Although the study by Önal et al[36] included only chronic patients, the high clinical utility of the Tinetti POMA-B might allow its use in all patients regardless of the time since the event. Furthermore, the presence of a trained caregiver during remote evaluation, as suggested by the authors, would allow assessment even in individuals at an earlier stage and with more significant balance impairment. Although the authors underlined this aspect, they did not provide any specific guidance regarding how the caregiver should be involved to support the remote assessment. This lack is in line with what was already observed on the important but understudied role of caregivers in supporting patients during video telehealth.[49] In our case, the definition of a clear and robust description of the caregiver's role may further increase the reliability of the assessment and ensure a safety evaluation of the subject.

Both motor recovery and balance evaluation should be considered to unlock the potential of telerehabilitation to expand access

Table 2 Clinical utility assessment.

Measurement Tool	Population	Time to Complete	Cost	Portability	Need for Specialist Equipment/Training	Total
ArmCAM[40]	Stroke	2	3	1	1	7
BBS[10,34]	Stroke	2	3	1	2	8
BBS[28]	PD	2	3	1	2	8
BBS[44]	MS	2	3	1	2	8
CRT[23]	PD	3	3	2	2	10
DGI[44]	MS	3	3	1	2	9
FMA-LE*[10,35,38]	Stroke	3	3	2	1	9
FMA-UE*[33,35,39]	Stroke	2	3	1	1	7
FRT[37]	Stroke	3	3	1	2	9
5TSST[21,24]	PD	3	3	2	2	10
5TSST[43]	MS	3	3	2	2	10
FTT[23]	PD	3	3	2	2	10
GRASSP*[42]	SCI	2	3	1	1	7
MDS-UPDRS*[25,30,26,29,31,32]	PD	2	3	2	1	8
MDS-UPDRS I-III*[22]	PD	2	3	2	1	8
MDS-UPDRS III*[27]	PD	3	3	2	1	9
9HPT[25]	PD	3	3	1	1	8
9HPT[45]	MS	3	3	1	1	8
Push-up test[41]	SCI	3	3	2	2	10
RTT[21]	PD	3	3	2	2	10
Step test[35]	Stroke	3	3	2	2	10
T25FWT[45]	MS	3	3	1	2	9
Tinetti-POMA-B[36]	Stroke	2	3	2	2	9
Tinetti-POMA-G[10]	Stroke	3	3	2	2	10
Timed Stance test[28]	PD	3	3	2	2	10
TRS[23]	PD	3	3	2	2	10
TUG[28,32]	PD	3	3	2	2	10
TUG[44]	MS	3	3	2	2	10

NOTE. Time to complete: 3≤10 min, 2=10-30 min, 1=30-60 min, 0≥1 h; cost: 3≤£100, 2=£100-£500, 1=£500−£1000, 0≥£1000 or unknown; portability: 2=yes easily (can fit in a pocket), 1=yes (in a briefcase or trolley), 0=no or very difficult; need for specialist equipment/training: 2=no, 1=yes, but simple and clinically feasible, 0=yes and not clinically feasible/unknown.

Abbreviations: 360° RTT, Rapid-Turns-Test; 5TSST, Five Times Sit-to-Stand Test; 9HPT, Nine-Hole Peg Test; ArmCAM, Arm Capacity and Movement Test; BBS, Berg Balance Scale; ClinROM, Clinician Reported Outcome; CRT, Coin Rotation Test; DGI, Dynamic Gait Index; F, female; FMA-LE, Fugl-Meyer Assessment—lower extremity subscale; FMA-UE, Fugl-Meyer Assessment—upper extremity subscale; FRT, Functional Reach Test; FTT, Finger Tapping Test; GRASSP, Graded Redefined Assessment of Strength, Sensation, and Prehension; MDC, minimal detectable change; MDS-UPDRS, Movement Disorder Society - Unified Parkinson Disease Rating Scale; MS, multiple sclerosis; ND, neurologic disorders; PD, Parkinson disease; PerFOM, performance-based outcome; SCI, spinal cord injury; T25FWT, Timed 25-Foot Walk Test; Tinetti-POMA-B, Tinetti Performance-Oriented Mobility Assessment—Balance subscale; Tinetti-POMA-G, Tinetti Performance-Oriented Mobility Assessment—Gait subscale; TRS, Tremor Rating Scale; TUG, timed Up and Go Test; y, years.

* Modified version of the scale.

to care and ensure the best rehabilitative pathway for people with stroke.

Unlike stroke, which requires intensive evaluations and monitoring mainly during the acute phases, other neurologic conditions are characterized by a progressive course requiring regular follow-up evaluations. This not only places a significant burden on health care systems but also exposes patients to logistical issues, particularly in advanced stages when mobility becomes increasingly challenging.[2] Among these disorders, MS is particularly prevalent and notably leads to a significant disability burden on younger individuals.[50] This underscores the critical importance of regular evaluations to promptly detect any clinical deterioration or progression, enabling the timely implementation of targeted rehabilitative interventions and preventing detrimental delays in treatment. In this context, remote assessment might be crucial to ensure adequate follow-up despite waiting lists for access to health facilities. Indeed, people with MS can be remotely evaluated by identifying several measures among the suggested assessment tools. The 9HPT and the T25FWT are part of the Multiple Sclerosis Functional Composite, a composite evaluation including a score for arm and hand function and a score for ambulation.[51] The Multiple Sclerosis Functional Composite represents a multidimensional assessment to measure the severity and clinical status of people with MS and to follow their evolution over time; adapting the motor part of the Multiple Sclerosis Functional Composite for remote administration may promote inclusion and accessibility to care for these patients.[45] Remote evaluation of walking function through the T25FWT requires several adaptations to make the assessment feasible and safe. In particular, the authors developed a screening questionnaire to determine whether the test could be performed and with what level of assistance by the caregiver; if the subject was able to perform the test but did not have enough space, this was replaced by a shorter version.[45] Furthermore, each participant received written instructions on the test setup, webcam

positioning, and safety recommendations. All these adaptations are helpful for ensuring the safety of the assessment. However, the T25FWT might not be applied to individuals with higher motor impairment or without a caregiver, limiting their possibility of being remotely evaluated. On the other hand, the presence of a caregiver could influence walking performance, giving the patient more confidence in the movement performed under the supervision of a familiar person, making its evaluation not comparable to the in-person assessment.

The 5TSST is suggested for remotely evaluating lower limb strength in people with MS.[43] In this case, the authors recommended considering the chair characteristics (height, depth, and presence or absence of armrests) to make the remote assessment reliable and comparable to the in-person evaluation.[43] Therefore, despite the abovementioned limitations, these instruments provide quick, simple, and cost-effective means of monitoring upper limb function and walking performance in patients with MS. Considering their essential role in daily life, these assessment tools could become pivotal components of routine evaluations for these patients or, at the very least, serve as valuable methods to identify individuals requiring more comprehensive assessments in health care facilities.

The clinical utility of our findings needs to consider several important aspects regarding the applicability of remote motor performance assessment through video conferencing. In fact, an essential requirement for a reliable remote assessment is the presence of adequate technological devices and internet connection sufficient to support a video conference. This aspect is particularly important for improving access to care for people living in rural areas.[52] However, many of the studies included in our review excluded from their recruitment all people without a stable internet connection or experience in using technological devices such as smartphones and computers.[10,21,24,30,35,40,41,43,44] This recruitment bias may overestimate the real applicability of remote evaluation, particularly in areas with limited broadband internet access. On the other hand, a poor internet connection could lead to errors in measurement unrelated to the measurement tool.[24,29,33,35,43] Only a few studies have offered solutions to ensure the necessary technological support to patients through providing video conferencing devices and free internet hotspots.[25,33] All these aspects, as well as the clinical utility and measurement properties of the assessment tools, must be considered to improve accessibility to care for people with impaired mobility living in rural areas with limited access to expensive technological solutions.

Study limitations

Although we performed a systematic review of the literature, our findings are affected by several limitations that might limit their applicability in clinics and research. First, we included only studies on people with neurologic conditions. Although this allowed us to focus on the population of interest, we may have excluded studies with crucial implications for the applicability and clinical utility of measurement tools only because they were conducted in a population other than that we included. As evidence of this, studies evaluating important aspects such as video and bandwidth quality[52] were excluded because they were conducted on healthy subjects. Second, some studies have only evaluated feasibility without investigating any measurement property;[21,22,26,29,31,32] although the applicability of a measurement tool requires that it be appropriate for specific patients, the absence of information about its reliability, validity, or responsiveness does not allow for drawing definitive conclusions about its use. Fourth, only a few studies scored at least adequate at the COSMIN quality assessment because several methodological flaws affect measurement properties. Many studies refer to reliability even when different modes of administration (remote vs. in-person),[23-25,27,28,30,34,35,39,42,44] assessment modalities (synchronous vs. asynchronous),[24,25,27,28,35,42] or different versions of the same scale[10] are compared, contrary to COSMIN's recommendations.[12] Additionally, the measurement error was affected by changes in assessment conditions,[10,34,42] the comparison of different modalities of administration introduced a systematic error not related to true changes in the measured construct,[53] particularly when an unstable internet connection further aggravated this aspect.[24,29,33,35,43] Finally, the high heterogeneity of the included studies in terms of population, domain of assessment, and measurement properties did not allow an aggregate data analysis, which would have been used as a starting point to formulate recommendations for each of the outcomes included. All these factors make identifying the clinical utility of the identified measurement tools challenging, and further studies with larger samples and higher methodological quality are needed.

Conclusions

Our systematic review identified several measurement tools for the remote motor performance assessment of people with neurologic disorders requiring only synchronous or asynchronous video conferencing without the use of sensor-based systems or computer applications. However, only a few of these methods can be suggested for use in clinics and research: the lower and upper extremity sections of the FMA and the Tinetti POMA-B for people with stroke and the 5TSST, the 9HPT and the T25FWT for patients with MS. In addition to highlighting the potential of these remote assessment tools for quick, cost-effective, and safe patient monitoring, this systematic review aimed to raise awareness about the need for greater methodological rigor to generalize individual findings. These aspects, together with an appropriate evaluation of both the available technological solutions and the need for adaptations to individual characteristics, would make remote measurement tools accessible for clinical practice beyond the research setting, ultimately benefiting patients and caregivers and optimizing clinical resources.

Supplier

a. Rayyan web app; Rayyan.ai.

Keywords

Multiple sclerosis; Parkinson disease; Psychometric; Rehabilitation; Spinal cord injury; Stroke; Traumatic brain injury; Telerehabilitation

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Data statements

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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