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SPECIAL CONTRIBUTION

PM&R

Telehealth in PM&R: Past, present, and future in clinical practice and opportunities for translational research

Adam S. Tenforde MD[1] | Joshua J. Alexander MD[2] | Marcalee Alexander MD[3] | Thiru M. Annaswamy MD, MA[4] | Conley J. Carr MD[5] | Philip Chang DO[6] | Monique Díaz MD[7] | Mary A. Iaccarino MD[1] | Stephen B. Lewis MD[8] | Carolyn Millett[9] | Sindhu Pandit MD, MBA[10] | Claudia P. Ramirez MD[11] | Robert Rinaldi MD[12] | Megan Roop[9] | Chloe S. Slocum MD, MPH[1] | Gene Tekmyster DO, MBA[13] | Deborah Venesy MD[14] | Monica Verduzco-Gutierrez MD[15] | Richard D. Zorowitz MD[16] | Todd R. Rowland MD[17]

[1]Department of Physical Medicine and Rehabilitation, Harvard Medical School, Spaulding Rehabilitation, Charlestown, Massachusetts, USA

[2]Department of Physical Medicine and Rehabilitation, University of North Carolina School of Medicine, Chapel Hill, North Carolina, USA

[3]Department of Physical Medicine and Rehabilitation, University of Alabama at Birmingham School of Medicine, Birmingham, Alabama, USA

[4]Department of Physical Medicine and Rehabilitation, Penn State Health Milton S. Hershey Medical Center Penn State College of Medicine, Hershey, Pennsylvania, USA

[5]Department of Physical Medicine and Rehabilitation, University of Alabama at Birmingham, Birmingham, Alabama, USA

[6]Department of Physical Medicine and Rehabilitation, Cedars-Sinai Medical Center, Los Angeles, California, USA

[7]Dignity Health, Santa Maria, California, USA

[8]Physiatry-Pharmacy Collaborative, NJ Institute for Successful Aging, Princeton, New Jersey, USA

[9]American Academy of Physical Medicine and Rehabilitation, Rosemont, Illinois, USA

[10]Ochsner Health System, New Orleans, Louisiana, USA

[11]Kelly Collaborative Medicine, Silver Spring, Maryland, USA

[12]Department of Physical Medicine and Rehabilitation, UT Southwestern Medical Center, Dallas, Texas, USA

[13]Department of Orthopedic Surgery, Keck Medicine of USC, Los Angeles, California, USA

[14]Cleveland Clinic, Cleveland, Ohio, USA

[15]Department of Rehabilitation Medicine, University of Texas Health Science Center at San Antonio, San Antonio, Texas, USA

[16]Department of Rehabilitation Medicine, MedStar National Rehabilitation Network, Georgetown University, Washington, District of Columbia, USA

[17]Duke University Hospital, Durham, North Carolina, USA

Correspondence
Adam S. Tenforde, Department of Physical Medicine and Rehabilitation, Harvard Medical School, Spaulding Rehabilitation, Spaulding Rehabilitation, 300 First Avenue, Charlestown, MA 02129, USA.
Email: atenforde@mgh.harvard.edu

Abstract

Telehealth refers to the use of telecommunication devices and other forms of technology to provide services outside of the traditional in-person health care delivery system. Growth in the use of telehealth creates new challenges and opportunities for implementation in clinical practice. The American Academy of Physical Medicine and Rehabilitation (AAPM&R) assembled an expert group to develop a white paper to examine telehealth innovation in Physical Medicine and Rehabilitation (PM&R). The resultant white paper summarizes how telehealth is best used in the field of PM&R while highlighting current knowledge

Adam S. Tenforde and Joshua J. Alexander—Co-chair for white paper.

deficits and technological limitations. The report identifies new and transformative opportunities for PM&R to advance translational research related to telehealth and enhance patient care.

INTRODUCTION

Telehealth refers to the use of telecommunication devices and other forms of technology to provide services outside of the traditional face-to-face health care delivery system. Most commonly, telehealth visits use both audio and visual communication performed synchronously between a provider and patient. A component of telehealth includes telerehabilitation, which is referred to in this white paper to encompass the delivery of therapies by allied health providers (e.g., physical, occupational, and speech therapists) using the telehealth platform. A 2017 report reviewed the limited number of studies specific to physiatry and offered potential applications of telehealth to advance health care in the specialty of Physical Medicine and Rehabilitation (PM&R).[1] Since then, the adoption and implementation of telehealth has grown rapidly, due in part to efforts to maintain health care delivery during the pandemic caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Studies suggest that physicians, therapists, and patients all rated their experiences to be favorable.[2,3]

The American Academy of Physical Medicine and Rehabilitation (AAPM&R) recognizes the ongoing challenges of physicians and their patients in using telehealth for health care delivery and the value of innovative strategies to address them. The objectives of this white paper are to summarize the innovative ways telehealth is being used in PM&R, identify current knowledge deficits and technological limitations, outline the strength of available evidence, and explore new and transformative opportunities for PM&R to advance translational research and patient care.

METHODOLOGY

In August of 2020, the AAPM&R Board of Governors requested that the Academy create a workgroup to examine telehealth innovation in PM&R. A workgroup was selected in late 2020 comprising a chair (T.R.R.) and six AAPM&R members (J.J.A., M.D., S.P., C.P.R., A.S.T., and D.V.) and first met in February 2021.

With input from the workgroup, the co-chairs of the white paper (A.S.T. and J.J.A.) identified telehealth content subtopics spanning inpatient and outpatient practices, including aspects of care unique to the specialty of PM&R, such as recognizing barriers to using telehealth faced by individuals with disabilities.

Literature reviews were conducted by topic authors in February and March of 2022 to identify key articles using search terms and PubMed, cross-referencing primary articles to recognize relevant articles, and an additional search was completed in August 2022. Findings were presented and discussed during two virtual meetings and developed into recommendations based on Strength of Recommendation Taxonomy (SORT).[4] The resulting SORT recommendations classified patient-oriented evidence as follows:

- Strength of recommendation A: recommendations from consistent and good-quality evidence.
- Strength of recommendation B: recommendations from inconsistent or limited-quality evidence.
- Strength of recommendation C: recommendations using disease-oriented studies, usual practice, opinion, or consensus.
- Strength of recommendation Unrated: recommendations that do not have sufficient evidence but may have preliminary evidence.

RESULTS AND KEY FINDINGS

Search terms, number of initial results, and final included references for each of 11 topics are presented in Table 1.

Informatics

The results of each search are summarized by section topic. For informatics, the software platform utilized to perform virtual visits should meet the needs of both providers and patients. Integration within the existing electronic health records (EHRs), total cost of ownership, and market penetration each determine feasibility and likelihood of adoption.[5] Telehealth platforms may require specific configurations for patients treated across the specialty of PM&R. Examples of strategies that can be considered by type of impairment can be found in Table 2.

PM&R physicians evaluate the potential barriers posed by impairments to ensure the successful completion of a visit. A task analysis can be useful to help identify the potential issues that may arise using telehealth platforms for each impairment. For example, one software program was found to interfere with augmentative and alternative communication when audio was enabled, defaulting the visit to yes/no interactions.[6] Patients with limited visual acuity or hand dexterity may experience difficulties with button placement for audio/video that is low contrast, very close together, or too far

TABLE 1 Search strategy and key articles.

Section topic	Search terms	Initial results	Key articles identified
Informatics	telehealth, EMR, EHR, integration	141	7
Telehealth Physical Examination	physical examination"[MeSH Terms] OR physical-examination [tiab] OR physical-exam [tiab]) AND (Telemedicine [Mesh] OR Internet-Based Intervention [Mesh] OR telemedicine OR telehealth OR mhealth OR "mobile health" OR teleconsult*) AND (musculoskeletal exam* OR neurologic* exam* OR pain assess*))	62	20
Evaluation and Treatment			
Telehealth Diagnostic Strategies	telediagnosis, rehabilitation	205	3
Telerehabilitation	telerehabilitation, therapeutics, therapy, treatments,	1579	25
Concussion	concuss* OR "mild traumatic brain" OR "head injr*" AND telehealth, OR telemedicine, OR telecare, OR mobile health, OR m-health, OR virtual	11	11
Spine and Pain Disorders	(virtual or telehealth or remote or telemedicine) and (spine)	70	48
Cancer Rehabilitation	telerehabilitation or tele-rehabilitation) OR (video visits)) OR (remote care or remote consultation)) OR (telehealth)) OR (telemedicine)) AND (((rehabilitation or physiatry) OR (rehabilitation medicine)) OR (physical medicine) AND (rehabilitation) AND (cancer or oncology); English Language	550	27
Pediatric Rehabilitation	telerehabilitation, telemedicine, telehealth, physiatry, rehabilitation, handicap, cerebral palsy, spasticity, brain injury, spinal dysraphism, spinal cord injury, amputation, mental deficiency, developmental disorder, developmental delay, intellectual impairment, special needs, disability Subterms: child* or infant* or infancy or newborn* or neonat* or baby or babies or kindergar* or adoles* or pediatric* or pediatric* or schoolchild* or school age* or preschool* or kid or kids or toddler* or teen or teens or teenager* or youth or youths or boy* or girl* or pubert* or pubescen* or prepubescen*	298	6
Neurorehabilitation	(Telehealth or telemedicine) and (rehabilitation or physiatry or physical medicine) and (stroke or spinal cord injury or brain injury or neurologic conditions or spasticity) and adults	311	3
Frailty and Cardiac Telerehabilitation in Post-Acute Care	frailty, physical frailty, cognitive frailty, frailty prevention, dementia prevention, post-acute telemedicine, rehospitalization prevention, cardiac tele-rehabilitation, mobile cardiac rehabilitation, home-based cardiac rehabilitation, 4Ms model of care, self-management support, post-hospital syndrome, post-hospital disability	234	41
Health Disparities	"health equity" AND ((telehealth) OR (telemedicine) OR (telecare) OR ("mobile health") OR (m-health))	290	3
Environmental Considerations	telerehabilitation, telemedicine, telehealth, climate change, carbon emissions	100	14

Abbreviations: EMR, electronic medical record; EHR, electronic health record.

apart. Ongoing work such as the Web Content Accessibility Guidelines (WCAG) aim to ensure telehealth platforms are accessible to everyone.[7,8]

PM&R physicians commonly evaluate and treat patients with chronic, long-term conditions. Existing data collection and display platforms within EHRs may be used to perform telehealth rehabilitation interventions. For example, studies have documented that telehealth is effective for monitoring diabetes, epilepsy management, and diet/nutrition.[9,10] The field of PM&R has an opportunity to expand evidence-based research to inform telehealth applications, as most studies are limited to feasibility, pilot data, and acceptability, reflecting early stage research.[10] Potential advances to apply telehealth within PM&R include VISYTER (Versatile and Integrated System for Telerehabilitation), which incorporates a portal that is integrated with EHR systems to provide a clinical workflow including status updates that can be used to facilitate discussion among all team members.[11]

TABLE 2 Examples of strategies to address impairments encountered during telehealth.

Feature	Impairment	Potential solution
Visual display	Vision	Create option to enlarge font size for visual impairments; in more advanced vision loss, alternative of auditory feedback and talk-to-text strategies for communication
Auditory output	Auditory	Ensure volume setting or peripherals are available to enhance auditory output (e.g., bone-conducting headphones)
Auditory input	Communication	Provide additional time or the use of a patient assistant to enhance communication
Use of keyboard	Motor	Peripheral keyboard with larger keys to reduce errors, talk to text
Use of trackpad	Motor	Alternative track pad, eye-tracking software to improve ability to respond to tasks
Technology to conduct visit	Access to health care platform	Use of smart phones or travel to peripheral centers that can allow for conducting telehealth visits

INFORMATICS RECOMMENDATIONS

SORT C: Expert opinion supports the use of telehealth integration into EHRs for PM&R practice, as supported by evidence demonstrating efficacy in the management of chronic medical conditions.

Future directions

- Hardware and software modifications are required to meet the needs of patients with specific impairments related to health conditions who are treated by PM&R physicians; condition-specific and disease-specific studies may validate the use of telehealth integration into patient management.

Telehealth physical examination

Although a detailed history can be effectively obtained using telehealth, it can be difficult to perform the physical examination such as providing tactile stimuli (e.g., pain with palpation, presence of warmth to suggest infection) or manual aspects (such as performing accurate range of motion of the hip or performing tests to evaluate for spasticity or rigidity of muscle groups). Modifications to standard physical examinations to assess neurological and musculoskeletal impairments or painful conditions may be necessary when conducted via telehealth (Table 3).[12,13] To address these barriers, caregivers or family members who are with the patient during the telehealth visit can be instrumental in assisting with the physical examination.[14] Clinicians should anticipate that these assisted examinations may require more time, particularly when evaluating older adults.[15,16]

Many studies have examined how telehealth physical examinations compare to in-person examinations for the diagnosis and management of neurological and musculoskeletal conditions. Studies have found that examinations performed via telehealth have findings similar to those performed in-person for patients with spinal conditions during pre-surgical evaluation,[17] patients with low back pain,[18,19] and patients presenting to the emergency department for evaluation of neurological symptoms.[15] Gait analysis and evaluation of appropriate cane height can be performed using the Performance-Oriented Mobility Assessment (POMA) gait scale with both moderate validity and inter-rater reliability.[20] One study of patients with Parkinson disease found that standardized performance measures such as the Timed Up and Go (TUG) test, Berg Balance Scale, timed stance test, steps to complete 360-degree turn, and lateral and functional reach tests could be assessed reliably using telehealth.[21]

Prior work comparing the components of the musculoskeletal examination between in-person and telehealth assessments has found some variability in terms of accuracy and arriving at a correct diagnosis. Hip and pelvis examinations conducted in-person versus via telehealth were found to have similar reliability in terms of inspection and function, but lower agreement in terms of palpation and range of motion, especially in older patients with more co-morbidities and/or a greater body mass index.[22] Another study found that when evaluating knee injuries, gait analysis was similar between in-person and telehealth examinations, but there was less agreement for functional testing and identifying ligamentous injuries.[16] However, a separate report suggested that in 89% of cases, clinicians performing knee assessments via telehealth arrived at the same diagnosis as those performing in-person examinations.[23] The diagnosis of nonarticular lower limb musculoskeletal conditions may also be similar using telehealth compared with in-person visits.[24] Range of motion of the elbow, wrist, and knee was similar for in-person compared to telehealth examinations,[20,23,24] although less-experienced providers had reduced precision of

TABLE 3 A system-based approach to performing and documenting a physical exam via telemedicine.

System	System sub-area	Adaptation to virtual care	Suggested documentation for normal exam
Vital signs		Evaluate for tachypnea, cyanosis, orthostatic symptoms as applicable. May ask patient for height/weight. If patient has heart rate monitor (wrist or chest) and/or automatic blood pressure cuff, can have them provide values	Normal rate of breathing, appears well-oxygenated without cyanosis, reports no dizziness or orthostatic changes when asked to stand for 5 minutes after sitting
General		Practitioner's observation, including alertness, general appearance	Alert, cooperative, well-appearing, no acute distress
Respiratory		Practitioner's observation, including labor of breathing, presence of cough or wheezing	Non-labored breathing, no cough or wheezing
Skin		Practitioner's observation of patient's skin for masses, lesions, or ulcers. Inspect and comment on any skin changes at anatomic site(s) post- injection	No lesions or ulcers visualized on exposed skin. No discharge, drainage, or redness at site(s) of prior injection
Psych		Practitioner's observation of patient's mood and affect	Normal mood, congruent affect; answers questions appropriately
Neuro	Mental status	Level of alertness, orientation to visit, able to identify objects and maintain attention to tasks	Alert and oriented to person, time, and reason for visit. Able to identify objects including items of clothing, electronic devices in use, and ability to perform serial 7s (or spell WORLD backwards if fluent in English or use an alternative more appropriate for education level)
	Speech	Rate of speech, word choice, and volume	Fluent and normal rate of speech, no word finding difficulties
	CN[a] I	If patient accompanied, patient may be presented with familiar smell (coffee, bread) to identify with eyes closed	CN I confirmed intact as patient able to accurately identify presented odor
	CN II	Practitioner's observation of pupils	Pupils equal and round
	CN III, IV, VI	Ask patient to gaze in different directions	Extraocular movements intact, no nystagmus, no ptosis
	CN V	Ask patient to clench and release jaw	Jaw movements intact and symmetric
	CN VII	Ask patient to smile, raise eyebrows	Symmetric facial movement and smile
	CN VIII	Practitioner's observation of patient's hearing ability	Hearing intact to normal voice
	CN IX/X	Practitioner's observation of vocal quality	Normal vocal quality, no hoarseness
	CN XI	Ask patient to shrug shoulders, rotate neck	Symmetric shoulder shrug and neck rotation
	CN XII	Ask patient to stick out tongue	Tongue protrudes midline
	Motor	Practitioner's observation of abnormal movement at rest including tremor, dystonia, clonus; instruct patient on rapid finger tapping, pronator drift	No tremor, dystonia, or clonus observed. Rapid finger tapping intact. No pronator drift.
	Tone	Practitioner's observation on voluntary movement, co-contraction, posturing with position changes	Patient able to perform full active movements, no co-contraction, no posturing with position changes
	Coordination	Practitioner instructs patient on performing rapid alternating movements, finger-to-nose with available targets (e.g., edge of computer screen), heel-to-shin	Rapid alternating movements intact and symmetric; finger-to-nose and heel-to-shin intact bilaterally.
	Proprioception	Practitioner instructs patient on performing Romberg and tandem walking tests	Negative Romberg; normal tandem walking
	Sensation	Practitioner asks patient or accompanying individual to gently touch appropriate dermatomal regions, simultaneously if possible, and report any abnormal sensation. May also provide diagram of dermatomes to further instruct patient. Practitioner can also ask patient to use tip of pencil and eraser to test sharp/dull sensation.	Sensation to light touch and sharp/dull subjectively intact

(Continues)

TABLE 3 (Continued)

System	System sub-area	Adaptation to virtual care	Suggested documentation for normal exam
	Strength	Practitioner's observation of whether patient can perform appropriate movements anti-gravity; heel and toe walking can provide additional information about dorsiflexion/plantarflexion strength	Strength at least anti-gravity in all four limbs. Able to walk on heels and toes without difficulty
Musculoskeletal	Gait	Practitioner's observation of patient's gait	Symmetric, non-antalgic, heel-to-toe gait
	Inspection	Practitioner's observation of relevant body regions as directed by patient and clinical suspicion	No asymmetry; no discoloration, erythema, or swelling; no obvious deformity
	Palpation	Practitioner instructs patient to find area(s) of tenderness, and guides patient to palpate relevant associated areas, sense temperature differences in adjacent region or contralateral side, and describe crepitus	No tenderness to palpation; no crepitus reported, equal warmth
	Range of Motion	Practitioner guides patient in performing movements to observe active range of motion	Full symmetric, active range of motion in bilateral shoulders, elbows, and knees
	Special Testing	Practitioner guides patient as appropriate for patient's chief complaint	

Note: Reused from reference 13 with permission.
[a]Cranial nerve.

measurements[25] and accuracy when evaluating elbow pronation and supination using telehealth.[26] In the upper extremity, telehealth shoulder evaluation yielded reliable estimates of shoulder function and range of motion limitations compared to in-person assessments[27,28] and the diagnosis of elbow conditions had high agreement.[29]

Table 3 lists key features of musculoskeletal and neurological examination by telehealth.

TELEHEALTH PHYSICAL EXAMINATION RECOMMENDATIONS

SORT A: Although aspects of the physical and neurological exam such as palpation and range of motion may have less accuracy using telehealth, elements of the telehealth virtual examination have similar agreement to in-person assessments for selected musculoskeletal and neurological conditions.

SORT C: Some aspects of the physical examination are limited using telehealth compared to in-person examination and require supplemental testing for improved accuracy.

Future directions

- Remote wearable devices including accelerometers may provide more accurate measures of strength, range of motion, and measures of spasticity and tone using haptic technology and require further study.

Augmentation of telehealth diagnostic strategies

Telehealth diagnostics may be improved compared with in-person diagnosis through the use of augmented measures such as external devices or medical assistants who are present with the patient.[30] For example, virtual reality (VR) may be used to evaluate both physical and cognitive function.[31-33] VR may be combined with augmented reality (AR) and haptic technology to improve assessment tools. The combination of VR or AR with devices such as robots, sensors, and wearables is referred to as extended reality (XR) and has been used in telehealth rehabilitation for remote monitoring, assessment, and telehealth diagnosis.[34-37] The use of XR has been proposed for management of Parkinson disease to augment the evaluation of motor function through the use of wearable technology.[38] Augmented Reality-based Telerehabilitation System with Haptics (ARTESH) is defined as "a telerehabilitation system which uses haptic feedback and depth sensing camera technology (Red-Green-Blue-Depth/RGB-D cameras) to allow a clinician and a patient to interact remotely through video, audio, and touch."[39] ARTESH compared to in-person evaluation was qualitatively measured by users with the highest ratings for ease and simplicity of use (86%) and quality of experience (85%), with lower ratings compared to in-person evaluation (58%) including limitations in measuring lower isometric strength and range of motion measures in the upper extremity. The ARTESH remote strength and range of motion assessments were compared to in-person evaluation of 15 patients presenting with

upper extremity pain and demonstrated variability for agreements in range of motion measures.[37]

AUGMENTATION OF TELEHEALTH DIAGNOSTIC STRATEGIES RECOMMENDATIONS

Unrated SORT: Our review identified few studies and suggests insufficient evidence to support use of VR, AR, or ER to assist with improving diagnostic accuracy in the field of PM&R.

Future directions

- Use of augmented reality and haptic technology requires further study given limitations in aspects of performing the musculoskeletal and neurological examination using telehealth.

Rehabilitation therapies delivered via telehealth (Telerehabilitation)

Systematic reviews have concluded that telehealth rehabilitation (also referred to as telerehabilitation) may result in similar to greater outcomes compared with in-person therapy for improving physical function in musculoskeletal conditions.[40,41] Multiple studies demonstrate the value of telerehabilitation in management of knee pain and knee osteoarthritis.[42,43] Telehealth rehabilitation following total knee arthroplasty has demonstrated similar outcomes in physical function[44,45] and higher patient satisfaction[46] compared with in-person care. The evidence may be stronger for improving functional mobility following total knee compared with total hip arthroplasty using telehealth.[47] More limited evidence documents outcomes using telehealth to increase physical activity in patients receiving active treatment for cancer or those living with cancer.[48]

Findings suggest that telehealth rehabilitation may be similar to traditional in-person care in the management of a number of neurological conditions including stroke,[49-51] while recognizing limitations due to variability of interventions and outcomes.[50,52] Telehealth using VR interventions may improve gait and balance impairments[53] and upper limb function after stroke.[54] Exercise games (also known as "serious games" or "exergames") resulted in greater gains than in-person therapy in upper limb function, activity, and participation.[55] In patients with stroke, speech and language pathologists using telerehabilitation may achieve similar outcomes in the management of aphasia[56] and improved activities of daily living.[57] Similarly, patients with neurological conditions resulting in cognitive impairments may see similar to greater gains using telerehabilitation compared with in-person rehabilitation, particularly in the treatment of executive function impairments.[58]

In contrast to stroke, fewer studies have been performed in other neurological conditions such as multiple sclerosis (MS) and pediatric traumatic brain injury (TBI). An earlier review concluded that patients with MS had a wide range of uses for telehealth but low evidence.[59] Subsequent work suggested that an integrated telerehabilitation approach demonstrated large effects to improve motor disability, with smaller effects observed for cognitive and participation outcomes such as depression in patients with MS.[60] Similar results were observed using telehealth rehabilitation over in-person care to improve walking and physical activity.[61] Use of VR in patients with MS may offer greater gains than in-person therapy for improving fatigue, quality of life, and balance.[62] More limited work in pediatric TBI suggests potential training programs (described as technology-delivered methods of addressing impairments in cognition and behavior) may be effective.[63]

REHABILITATION THERAPIES DELIVERED VIA TELEHEALTH (TELE REHABILITATION) RECOMMENDATIONS

SORT A: Telerehabilitation treatment can result in equivalent functional outcomes in the management of knee osteoarthritis and after cerebrovascular accident.

SORT C: The available studies outside knee osteoarthritis and stroke management have a lower level of evidence; small comparative trials and primary sources of consensus documents and opinion pieces by external experts suggest that other musculoskeletal and neurological diagnoses may be appropriate to treat using telerehabilitation.

Future directions

- Additional studies may help validate the use of customized telerehabilitation solutions for different patient populations including spinal cord injury (SCI) and TBI, pediatric populations, and for individuals with compromised immune systems from cancer who would benefit from avoiding in-person visits.

Concussion: Evaluation and management

Telehealth to evaluate and manage concussion is an emerging health care delivery strategy. The potential to expand the care of patients with concussion using

telehealth is strong including the ability to perform clinical interviews, cognitive assessments, education, activity guidance, and medication management, with more modest need for physical examination and point of care intervention. However, no randomized trials have compared outcomes for patients with concussions using telehealth compared with in-person visits. Evidence supports the feasibility of telehealth to monitor concussion symptoms, as veterans with concussion randomized to use a smart phone application had a greater reduction of symptoms compared to in-person care.[64]

Three primarily descriptive studies evaluated the use of telehealth in the treatment of pediatric populations with concussion. One study reported a reduction in concussion symptoms using a mobile application during a 6-week exercise intervention.[65] A smaller patient cohort with concussion managed via telehealth showed a 90% recovery rate.[66] Symptom reporting after concussion with a mobile app demonstrated a 74% retention rate in participation.[67] One study described evaluation and treatment of 20 pediatric patients using telehealth consultation for 90% and management for 80% of all patients.[68] Overall, 90% met clinical recovery and cost avoidance was estimated to be $40,973.

The limited studies in the diagnosis of concussion reported high agreement between telehealth and in-person for sideline assessment of acute sport concussion,[5] for triage of pediatric patients with head injury to inpatient care or to a teleconcussion program,[69] and for military TBI using teleneurology consultation to determine in-theater care or evacuation.[70] The management of concussion in 18 pediatric patients using telehealth was described with 10 patients cleared for return to play in a median of 15.5 days.[71] Collectively these studies suggest that early neurotrauma triage may be augmented using telehealth, but there is insufficient evidence to support replacing in-person evaluation of patients with more advanced brain injury.

The satisfaction in using telehealth for management of concussion may vary by population. Military service members enrolled in telehealth for concussion found a high degree of patient and provider satisfaction.[72] Telehealth care for adolescents with concussion achieved similar levels of therapeutic alliance for the patients but reduced for their caregivers.[73]

CONCUSSION RECOMMENDATIONS

SORT B: Evidence suggests that concussion/mild TBI (mTBI) may be managed with similar outcomes using telehealth compared to in-person visits for neurobehavioral aspects following concussion.

Unrated SORT: Insufficient level of evidence to provide SORT rating regarding how telehealth can be used for prognosis following concussion/mTBI.

Future directions

- Telehealth should be evaluated as a strategy to ensure compliance with symptom resolution and full return to sports and school following mTBI. Telehealth should be evaluated for facilitating return to work and restoring activities of daily living (ADLs) in adults with non–sports-related concussion. Potential strategies include developing patient registries that characterize telehealth use and validated outcome measures.

Management of spine disorders and pain

Telehealth can be used effectively for evaluating and treating patients with spine disorders. Initial evaluation and triage via telehealth has shown high patient satisfaction and capacity to progress with treatment plans in certain spine disorders.[74-77] Methods for performing the spine exam have been proposed and discussed[78-84] with some studies demonstrating high agreement of telehealth compared to in-person examinations,[17,19,85-87] and with more limited studies evaluating VR.[88] Telehealth may be particularly effective for the management of patients with spine disorders who have both advanced imaging and appropriate patient history available, including determining interventional procedures and spine surgery.[89] This is supported by a consistency of recommendations and minimal differences between telehealth and an in-person visit used to determine a procedural or surgical plan.[90-95] Use of telehealth has been shown to result in high physician confidence to develop treatment plans,[96,97] high patient satisfaction[98-100] particularly for follow-up visits[101] and management of low back pain,[102] including exercise programs.[103]

Although studies are currently limited on telehealth use for evaluating how a patient reports treatment response following the use of procedures to alleviate pain, applications of telehealth visits compared to in-person visits have been evaluated in the management of chronic pain conditions of Achilles tendinopathy and plantar fasciitis.[104] Investigators have identified similar outcomes using a telehealth visit compared to in-person visit to monitor the response to shockwave therapy and noted the follow-up level of care was billed lower, in part due to time-based billing practices. A smaller report found that a similar proportion of patients met patient-reported outcome measures when initially evaluated using telehealth versus in-person prior to receiving extracorporeal shockwave therapy.[105] Patients evaluated using telehealth compared to in-person had a similarly high level of agreement of primary diagnosis prior to extracorporeal shockwave therapy.[106]

Telehealth may also address barriers to receiving spine care. Although spine telehealth services and

management plans varied by geography and socioeconomic groups early during the coronavirus disease 2019 (COVID-19) pandemic,[107,108] adoption of telehealth services may increase access to specialty care for patients in remote areas and decrease economic burden[109,110] while reducing missed visits for patients of lower socioeconomic status.[111] The use of remote services for triage can produce significant cost savings for both health care systems and patients.[112]

MANAGEMENT OF SPINE DISORDERS AND PAIN RECOMMENDATIONS

SORT A: Telehealth offers a viable and effective medium to assess patients with spine conditions for treatment and allows for the formulation of an accurate and consistent treatment plan that includes surgical and procedural care.

SORT B: Telehealth evaluations offer an efficient means of preoperative and preprocedural assessment of spine pathology.

SORT C: There is limited evidence for the use of telehealth to diagnose complex spine conditions, largely due to the paucity and quality of available studies.

Future directions

- The feasibility of using telehealth to determine the appropriateness for interventional spine procedures and pain treatments and follow-up visits may result from tracking outcome measures to evaluate efficacy.
- Prospective investigations with longitudinal follow-up evaluating clinical outcomes may determine the relative value of telehealth compared with in-person visits in the management of musculoskeletal and neurological conditions.

Cancer rehabilitation

Telehealth may serve as a strategy to deliver rehabilitation to patients with cancer. In 2019, more than 16.9 million Americans had a history of cancer and, in 2022, there are expected to be 1.9 million new cancer cases diagnosed in the United States.[113] Cancer rehabilitation can improve functional status and the quality of life of patients with cancer but is limited to tertiary medical centers[114] and often requires longer travel distances to obtain care.[115,116] Earlier strains of COVID-19 were found to affect individuals with cancer much more severely, with mortality rates exceeding 20%,[117,118] and telehealth services can keep patients safe from communicable disease and increase access and convenience of care. High levels of satisfaction have been reported from both patients and providers participating in telehealth cancer rehabilitation visits,[119-121] although decreased satisfaction was noted for providers evaluating a new complaint, problems related to a neuromusculoskeletal issue, or lymphedema.[120,121] Planning prior to telehealth visits may be important, as 11% of all telehealth assessments and follow-up encounters were identified as requiring an in-person appointment indicating inefficient visits and possibly increased cost of care.[121]

Telehealth may facilitate exercise during cancer rehabilitation, helping patients achieve regular physical activity as recommended by American College of Sports Medicine, the National Comprehensive Cancer Network, and the American Cancer Society.[122-124] Multiple single-arm feasibility studies and case series have shown that telehealth-based exercise interventions help improve quality of life and increase physical function.[125-135] Similar results were found in six randomized control trials and two reviews, although there was significant heterogeneity in the exercises performed, the telehealth platform used, and the outcome measures recorded.[136-143] Conversely, two other reviews indicate that there is little evidence to support that telehealth exercise interventions resulted in higher physical function in patients with cancer.[48,144]

CANCER REHABILITATION RECOMMENDATIONS

SORT B: Cancer rehabilitation may be advanced using telehealth-based exercise interventions aimed to improve quality of life, physical function, and adherence to physical activity recommendations.

SORT C: In cancer rehabilitation, patients presenting with stable problems, medication prescription/titration, or education/counseling can be managed with telehealth.

Future directions

- Future areas of study should include exploring cost differences between telehealth and in-person visits, effects of telehealth on meaningful patient outcomes, effects of telehealth on overall health care utilization, and standardization of telehealth-based exercise interventions and outcome measures in research.

Pediatric rehabilitation

Research characterizing the use of telehealth in pediatric PM&R is not well described in the literature. A survey study of 78 pediatric PM&R physicians from multiple practice settings (80% academic setting, 13%

non-academic hospital-based practice, and 7% private practice) reported that 14.5% of respondents used telehealth earlier compared with the use by nearly all (97.4%) since the start of the COVID-19 pandemic. Most physicians were satisfied (85%) and "strongly agreed" or "agreed" that they would expand their use of telehealth to patients who live in remote geographic areas or have barriers to access clinical care, whereas a majority (57%) planned to expand use for all patients in their practices.[145] A recent cluster-randomized, crossover study investigating parent and PM&R physician experiences and perceived quality of care between telehealth-based school health clinic visits and in-person clinic visits demonstrated that a telehealth model of care for children with special health care needs was equal to an in-person visit both in experience and perceived quality of care.[146] Although both studies are descriptive, each suggests high acceptance of telehealth rehabilitation models in pediatric PM&R practice.

PEDIATRIC REHABILITATION RECOMMENDATIONS

SORT C: Pediatric rehabilitation can be delivered effectively using telehealth with outcomes similar to in-person visits.

Future directions

- Pronounced gaps in pediatric PM&R-specific telehealth research exist, including the assessment of cost-effectiveness/economics/school days saved and missed, quality of care, satisfaction (provider and patient), novel applications and models of care, and functional outcomes. It is imperative that more pediatric-specific PM&R research be done to capture these outcomes related to use of telehealth rehabilitation.

Neurorehabilitation

Telehealth in PM&R neurorehabilitation presents challenges, as impairments resulting from brain injuries and SCIs create barriers to participating in telehealth visits. Mental status or speech deficits may prevent patients from providing adequate histories. Motor strength deficits, apraxia, and muscle tone/spasticity may prevent patients from cooperating with physical examinations. Thus these patients may require assistance during the telehealth visit.

Published work specific to telehealth neurorehabilitation within PM&R are limited to reviews for patients with SCI. One review identifies categories of communication: provider to provider, direct to consumer, store-and-forward, web-based treatments, and interactive home monitoring studies.[147] Proposed methods of telehealth communication for patients with SCI may include audio-only, audio-visual, and other platforms. A second review advocates for telehealth to be utilized for transitions of care, access to care in rural areas, preventive health and wellness, bowel and bladder management, chronic pain, anxiety, and depression.[148]

A separate publication from the neurology literature that applies to PM&R practice advocates for the use of telehealth visits in the management of neurological conditions to minimize time lost from work and eliminate the need for transportation to complete an in-person visit, along with avoiding the costs and logistics of parking.[149] The authors concluded that neurorehabilitation telehealth visits were more successful for follow-up appointments with established patients, patients with stable diagnoses, visits not requiring interventions, and visits for medication management.

NEUROREHABILITATION RECOMMENDATIONS

SORT B: Limited evidence suggests efficacy and acceptance of telerehabilitation models in neurological PM&R practice.

Future directions

- Expansion of studies during acute inpatient rehabilitation along with outpatient follow-up management for conditions in patients with TBI, stroke, and other neurological impairments should evaluate outcomes to further substantiate these findings.

Frailty and cardiac telerehabilitation in post-acute care

Older patients who are hospitalized often develop hospital-associated functional decline and disability.[150-152] This can occur from the functional manifestations of the index diagnosis itself or from known co-morbidities but also from preventable risk factors connected to the hospital experience. These risk factors include enforced immobility, poor nutrition, complex medication regimens, disrupted sleep, and stressful environments. Evidence-based frameworks for managing similar risk factors include cardiac rehabilitation, the 4Ms model for an "age-friendly health system,"[153-155] the Acute Care for Elders model,[156] and the Lancet Commission findings for dementia prevention.[157] These multi-modal, best-practice models for care target improved functional capacity, improved cardiorespiratory fitness, and

reduced frailty as principal end points for the care of older adults. They center care delivery around what matters most to older patients—maximizing functional capacity and independence at home.[158]

Traditional skilled nursing facilities, home care agencies, and nurse-navigator programs connect post-acute patients to traditional medical and rehabilitation services but often fail to integrate standardized best practices,[152] such as routinely measuring and monitoring cardiorespiratory fitness,[159] frailty,[160] or quality of life throughout the post-acute episode. Self-management education (such as medication adherence) and coaching support are limited in post-acute care to treat chronic conditions and improve lifestyle, both of which have the potential to enhance mobility and cognition within aging populations.[160-163] These same gaps are observed in pre-acute models of primary care and may result in accelerated frailty, increased falls, cognitive decline, and the need for unplanned acute hospitalizations for older adults residing in the community.[160,164]

Providers in PM&R may utilize telehealth to address the gaps in care for debilitated older patients and those requiring cardiac rehabilitation. For example, telehealth services may be reimbursable for PM&R providers including home-based consultations, annual wellness visits, remote patient monitoring, and chronic care management, which may expand the delivery of tech-enabled versions of medical rehabilitation or multi-modal cardiac rehabilitation in the home after discharge from a hospital or skilled nursing facility. Medical and cardiac rehabilitation delivered through telehealth may enhance patient self-management support for an expanded list of evidence-based risk factors and co-morbidities identified to affect fitness, functional capacity, and quality of life at home.[160,161,165,166]

Home-based cardiac rehabilitation, facilitated by telehealth and remote patient monitoring, has been shown to be as effective and safe as center-based settings.[162,163,167-170] Data collected in the home from wearables and from self-reported outcome measures offer the promise of improving advanced data analytics such as machine learning for enhanced decision support of both providers and patients.[171] Telehealth has the potential to transform pre- and post-acute care by providing home-based programs that may improve fitness, functional capacity, and quality of life for most chronic health conditions, including in patients receiving cardiac rehabilitation.[159,160,166,172-175]

FRAILTY AND CARDIAC TELEREHABILITATION IN POST-ACUTE CARE RECOMMENDATIONS

SORT A: Home-based, technology-enabled cardiac rehabilitation to prevent cardiac-related frailty can be delivered as effectively as center-based care.

SORT C: Limited evidence suggests that the core components of multi-modal cardiac rehabilitation can improve fitness and functional capacity and prevent hospitalization within non-cardiac senior populations delivered in outpatient settings.

Future directions

- Future research may substantiate the value of cardiac telerehabilitation across different post-acute settings. Future research should explore whether machine learning algorithms can enhance decision support using personalized home-based cardiac rehabilitation data.
- Future research should report on cardiac rehabilitation outcomes for non-cardiac patients as a strategy to rehabilitate frailty and pre-frailty and to prevent hospitalizations.

Health care disparities

Telehealth offers tremendous promise to expand access to physiatric care for many individuals with both acute and chronic impairments from disabilities and injuries. However, although the COVID-19 pandemic accelerated the integration of telehealth of many health systems for both inpatient and outpatient care, vulnerable and marginalized patients still face significant barriers to accessing telehealth services. For example, during the early stages of the COVID-19 pandemic, patients with high social vulnerability had less access to videoconferencing technology, were more likely to access primary care services via telephone,[176] and had more limited benefits in telehealth used for stroke care.[177] Multi-level interventions, including but not limited to access to technology platforms, are required to address the health needs of underserved populations across the care continuum, range of impairments, and lifespan for all patients.[178] The universal design of telehealth programs and workflows should equitably expand access to telehealth for populations with cognitive disability and/or hearing or vision impairment, and account for the involvement of caregivers or interpreters used during the clinical encounter. Physicians and health systems must also engage in advocacy to champion accessible design features in telehealth platforms that improve patient access. The financial landscape of health care delivery creates ongoing challenges that limit access and delivery of telehealth. These obstacles include restrictions or elimination of reimbursement to health care providers and facilities along with the lack of incentives to promote ongoing services, particularly to the most vulnerable.

TABLE 4 Key SORT statements by topic.

Section Topic	SORT Rating[a]	Statement
Informatics	C	Expert opinion supports use of telehealth integration into EHR for PM&R practice, as supported by evidence demonstrating efficacy in management of other chronic medical conditions
Telehealth physical exam	A	While aspects of the physical and neurological exam such as palpation and range of motion may have less accuracy using telehealth, elements of the telehealth virtual examination have similar agreement to in-person assessments for selected musculoskeletal and neurological conditions
	C	Some aspects of the physical examination are limited using telehealth compared to in-person examination and require supplemental testing for improved accuracy
Augmentation of telehealth diagnostic strategies	Unrated	Our review identified few studies and suggests insufficient evidence to support use of virtual, augmented or extended reality to assist with improving diagnostic accuracy in the field of PM&R
Telerehabilitation	A	Telerehabilitation treatment can result in equivalent functional outcomes in the management of knee osteoarthritis and after cerebrovascular accident
	C	The available studies outside knee osteoarthritis and stroke management have lower level of evidence; small comparative trials and primary sources of consensus documents and opinion pieces by external experts suggest other musculoskeletal and neurological diagnoses may be appropriate to treat using telerehabilitation
Concussion	B	Evidence suggests concussion/mTBI may be managed with similar outcomes using telehealth compared to in-person visits for management of neurobehavioral aspects following concussion
	Unrated	Insufficient level of evidence to provide SORT rating regarding how telehealth can be used for prognosis following concussion/mTBI
Management of spine and pain disorders	A	Telehealth offers a viable and effective medium to assess patients with spine conditions for treatment and allows for formulation of an accurate and consistent treatment plan that includes surgical and procedural care
	B	Telehealth evaluations offer an efficient means of pre-operative and pre-procedural assessment of spine pathology
	C	Limited evidence supports use of telehealth to diagnose complex spine conditions, largely from the paucity and quality of available studies
Cancer rehabilitation	B	Cancer rehabilitation may be advanced using telehealth-based exercise interventions aimed to improve quality of life, physical function, and adherence to physical activity recommendations
	C	In cancer rehabilitation, patients presenting with stable problems, medication prescription/ titration, or education/counseling can be managed with telehealth
Pediatric rehabilitation	C	Pediatric rehabilitation can be delivered effectively using telehealth with similar outcomes to in-person visits.
Neurorehabilitation	B	Limited evidence suggests efficacy and acceptance of telerehabilitation models in neurological PM&R practice
Frailty and cardiac telerehabilitation in post-acute care	A	Home-based, technology enabled post-acute care including cardiac rehabilitation to prevent cardiac-related frailty can be delivered just as effectively as center-based care
	C	Limited evidence suggests that the core components of multi-modal cardiac rehabilitation can improve fitness, functional capacity and prevent hospitalization within non-cardiac senior populations delivered in outpatient settings
Health disparities	C	Expert opinion supports telehealth benefits for patients with physical and cognitive disabilities by addressing barriers to accessing care. Patients with neurological conditions often have physical and mental impairments that necessitate telehealth delivery of care in PM&R practice. Furthermore, the elevated risk for secondary complications and financial costs associated with traveling longer distances for in-person care (e.g., pressure injuries related to long car or van rides, time missed from work or school) are best addressed by preserving access to telehealth particularly in the most vulnerable and marginalized patients with disabilities
Environmental considerations	A	Telehealth results in positive environmental impact compared to traditional in-person visits
	C	Using telehealth may facilitate remote monitoring and earlier interventions for persons with disabilities who are disproportionately affected by weather disasters and require disaster aid

[a]Strength of Recommendation Taxonomy (SORT) A: recommendations from consistent and good-quality evidence; B: recommendations from inconsistent and limited-quality evidence; C: recommendations using disease-oriented studies, usual practice, opinion, or consensus; Unrated: recommendations that do not have sufficient evidence but may have preliminary evidence.

HEALTH CARE DISPARITIES RECOMMENDATIONS

SORT C. Expert opinion supports telehealth benefits for patients with physical and cognitive disabilities by addressing barriers to accessing care. Patients with neurological conditions often have physical and mental impairments that necessitate telehealth delivery of care in PM&R practice. Furthermore, the elevated risk for secondary complications and financial costs associated with traveling longer distances for in-person care (e.g., pressure injuries related to car or van rides, time missed from work or school) are best addressed by preserving access to telehealth, particularly in the most vulnerable and marginalized patients with disabilities.

Future directions

- Advocacy is critical to ensure that patients with disabilities have access to telehealth care.
- Future research to evaluate barriers and access to telerehabilitation diagnosis and treatments is necessary to evaluate outcomes in populations with health disparities.

Environmental considerations

Climate change is considered the biggest health care problem of the 21st century and individuals with disabilities are among the most susceptible to the effects of climate change.[179] Telehealth decreases carbon emissions and air pollution associated with vehicular travel for both patients and providers and can be beneficial in creating a carbon-neutral health care system. This is important to consider both domestically and globally given that 14 countries have made a pledge for carbon neutrality as have a number of health care systems.[180]

Studies on the environmental impact of telehealth include both prospective and retrospective studies and all demonstrated consistent findings of reduced CO_2 emissions across geography and patient populations served.[181-190] One study evaluated the environmental impact of telehealth in an urban academic rehabilitation setting in patients using telehealth, including one-third of telehealth patients who were non-ambulatory, and estimated avoiding an average travel distance of 95 miles, resulting in decreased CO_2 and other organic gas outputs.[191] Multiple reports emphasized the savings to patients of time and financial costs of travel and hotel.[1,68,184,186,188]

Telehealth may also serve an important role in early warning capacity and assist in natural disaster response. This is critical for addressing health concerns resulting from climate change that affect patients with impairments such as reduced mobility or pulmonary function. For example, the ongoing study Mitigating the Health Effects of Desert Dust Storms Using Exposure-Reduction Approaches (MEDEA) childhood asthma study aims to use ehealth and epidemiologic strategies to compare indoor versus outdoor interventions to protect children with asthma from Saharan dust storms[192] using wearable global positioning system (GPS) alerts actigraphy, health parameter sensors, and air pollution samples to assess exposure and outcomes. Telehealth may serve as an alternative strategy to assist during natural disasters and eliminate the effects of carbon emissions related to travel.[193]

Quantifying outcomes related to sustainability can include using techniques such as a carbon calculator or through further education, advocacy, or research.[194]

ENVIRONMENTAL CONSIDERATIONS RECOMMENDATIONS

SORT A: Telehealth results in a positive environmental impact compared to traditional in-person visits.

SORT C: Using telehealth may facilitate remote monitoring and earlier interventions for persons with disabilities who are disproportionately affected by weather disasters and require disaster aid.

Future directions

- Measuring the benefits of telehealth on environmental impact should include the use of a carbon calculator.[179]

SUMMARY

Telehealth has multiple uses within the field of PM&R and is expected to grow in level of evidence for patient-specific conditions. Telehealth can improve access to care over in-person encounters but limited studies document outcomes. The current state of telehealth in the field of PM&R supports ongoing use for a variety of patients, particularly those with chronic conditions, as a substitute for and complementary to in-person visits (Table 4). This white paper highlights levels of evidence for key topics; this is not intended to be expansive to all aspects of PM&R practice. Some providers and patients may require or prefer in-person visits over telehealth. Future work may help characterize the value of telehealth within condition-specific populations while identifying strategies to ensure impairments do not limit access to this care. The value of telehealth for cost savings, improving quality of care, and addressing environmental impacts of traditional face-to-face encounters will support future use.

DISCLOSURE

JJA: Own shares of Doximity (DOCS). SBL: Founder/Developer, HEALTHGAMEPLAN, a Digital Cardiac Tele-Rehabilitation Platform. MA: Author *Telerehabilitation: Principles and Practice*: Editor-in-Chief, *The Journal of Climate Change and Health*. MR & CM: American Academy of Physical Medicine and Rehabilitation (AAPM&R) Staff. SP: Employee, full-time, for Salesforce, a publicly traded company. NYSE: CRM. RR: National Institutes of Health (NIH) Grant for Collaborative study with University of Washington, Seattle Children's Hospital; PI of study—Seattle Children's. Hangar Live—national svmposium KeV note speaker; paid. Hannah, Campbell, and Powel Expert testimony work; paid. AAPM&R Board of Directors 2017-2O21; unpaid. AAPM&R BOLD Steering Committee member 2020- present; unpaid. TRR: CMIO for HealthGamePlan, CMO for Vitalflo Health, stock options Vitalflo Health. GT: Boston Scientific/Vertiflex, YHR Law, AO Spine, North American Spine Society (NASS)—Patient Safety Committee. DV: Past President, AAPM&R. Remaining authors—No disclosures.

ORCID

Adam S. Tenforde https://orcid.org/0000-0002-3966-8070
Thiru M. Annaswamy https://orcid.org/0000-0002-3969-9221
Philip Chang https://orcid.org/0000-0003-1194-5440
Mary A. Iaccarino https://orcid.org/0000-0001-9020-9390
Megan Roop https://orcid.org/0000-0002-6644-6852
Gene Tekmyster https://orcid.org/0000-0002-6644-0928
Monica Verduzco-Gutierrez https://orcid.org/0000-0003-0964-5908
Richard D. Zorowitz https://orcid.org/0000-0001-8938-786X

REFERENCES

1. Tenforde AS, Hefner JE, Kodish-Wachs JE, Iaccarino MA, Paganoni S. Telehealth in physical medicine and rehabilitation: a narrative review. *PM R*. 2017;9(5S):S51-S58.
2. Tenforde AS, Borgstrom H, Polich G, et al. Outpatient physical, occupational, and speech therapy synchronous telemedicine: a survey study of patient satisfaction with virtual visits during the COVID-19 pandemic. *Am J Phys Med Rehabil*. 2020;99(11):977-981.
3. Tenforde AS, Iaccarino MA, Borgstrom H, et al. Telemedicine during COVID-19 for outpatient sports and musculoskeletal medicine physicians. *PM R*. 2020;12(9):926-932.
4. Ebell MH, Siwek J, Weiss BD, et al. Strength of recommendation taxonomy (SORT): a patient-centered approach to grading evidence in the medical literature. *J Am Board Fam Pract*. 2004;17(1):59-67.
5. Vargas BB, Shepard M, Hentz JG, Kutyreff C, Hershey LG, Starling AJ. Feasibility and accuracy of teleconcussion for acute evaluation of suspected concussion. *Neurology*. 2017;88(16):1580-1583.
6. Valdez RS, Rogers CC, Claypool H, et al. Ensuring full participation of people with disabilities in an era of telehealth. *J Am Med Inform Assoc*. 2021;28(2):389-392.
7. Valdez R, Wellbeloved-Stone C, Lemke M, et al., editors. *Accessibility and beyond: Designing consumer health IT for disabled individuals. I-PrACTISE* (2017), Madison, WI.
8. Web Accessibility Initiative W3C. Web Content Accessibility Guidelines (WCAG) 2 Level AAA Conformance. [cited 2020 October 29]. Available from: https://www.w3.org/WAI/WCAG2AAA-Conformance
9. Lewinski AA, Drake C, Shaw RJ, et al. Bridging the integration gap between patient-generated blood glucose data and electronic health records. *J Am Med Inform Assoc*. 2019;26(7):667-672.
10. Gandrup J, Ali SM, McBeth J. Remote symptom monitoring integrated into electronic health records: a systematic review. *J Am Med Inform Assoc*. 2020;27(11):1752-1763.
11. Parmanto B, Saptono A, Pramana G, et al. VISYTER: versatile and integrated system for telerehabilitation. *Telemed J E Health*. 2010;16(9):939-944.
12. Verduzco-Gutierrez M, Bean AC, Tenforde AS, Tapia RN, Silver JK. How to conduct an outpatient telemedicine rehabilitation or Prehabilitation visit. *PM R*. 2020;12(7):714-720.
13. Wahezi SE, Duarte R, Kim C, et al. An algorithmic approach to the physical exam for the pain medicine practitioner; a review of the literature with multidisciplinary consensus. *Pain Med*. 2022;23:1489-1528.
14. Noutsios CD, Boisvert-Plante V, Laberge E, Perez J, Ingelmo P. The telemedicine-based pediatric examination of the back and lower limbs: a narrative review. *J Pain Res*. 2021;14:2959-2979.
15. Awadallah M, Janssen F, Korber B, Breuer L, Scibor M, Handschu R. Telemedicine in general neurology: interrater reliability of clinical neurological examination via audio-visual telemedicine. *Eur Neurol*. 2018;80(5–6):289-294.
16. Scheidt S, Kehrer M, Jaenisch M, et al. A feasibility pilot study on the use of telemedicine for the examination of the knee joint. *Z Orthop Unfall*. 2022;160(1):93-98.
17. Goyal DKC, Divi SN, Schroeder GD, et al. Development of a telemedicine neurological examination for spine surgery: a pilot trial. *Clin Spine Surg*. 2020;33(9):355-369.
18. Truter P, Russell T, Fary R. The validity of physical therapy assessment of low back pain via telerehabilitation in a clinical setting. *Telemed J E Health*. 2014;20(2):161-167.
19. Piche J, Butt BB, Ahmady A, Patel R, Aleem I. Physical examination of the spine using telemedicine: a systematic review. *Global Spine J*. 2021;11(7):1142-1147.
20. Venkataraman K, Amis K, Landerman LR, Caves K, Koh GC, Hoenig H. Teleassessment of gait and gait aids: validity and interrater reliability. *Phys Ther*. 2020;100(4):708-717.
21. Russell TG, Hoffmann TC, Nelson M, Thompson L, Vincent A. Internet-based physical assessment of people with Parkinson disease is accurate and reliable: a pilot study. *J Rehabil Res Dev*. 2013;50(5):643-650.
22. Jaenisch M, Kohlhof H, Touet A, et al. Evaluation of the feasibility of a Telemedical examination of the hip and pelvis-early lessons from the COVID-19 pandemic. *Z Orthop Unfall*. 2021;159(1):39-46.
23. Richardson BR, Truter P, Blumke R, Russell TG. Physiotherapy assessment and diagnosis of musculoskeletal disorders of the knee via telerehabilitation. *J Telemed Telecare*. 2017;23(1):88-95.
24. Russell T, Truter P, Blumke R, Richardson B. The diagnostic accuracy of telerehabilitation for nonarticular lower-limb musculoskeletal disorders. *Telemed J E Health*. 2010;16(5):585-594.
25. Mehta SP, Kendall KM, Reasor CM. Virtual assessments of knee and wrist joint range motion have comparable reliability with face-to-face assessments. *Musculoskeletal Care*. 2021;19(2):208-216.
26. Chanlalit C, Kongmalai P. Validation of the telemedicine-based goniometry for measuring elbow range of motion. *J Med Assoc Thai*. 2012;95(Suppl 12):S113-S117.

27. Goldstein Y, Schermann H, Dolkart O, et al. Video examination via the smartphone: a reliable tool for shoulder function assessment using the constant score. *J Orthop Sci*. 2019;24(5):812-816.
28. Wang G, Fiedler AK, Warth RJ, Bailey L, Shupe PG, Gregory JM. Reliability and accuracy of telemedicine-based shoulder examinations. *J Shoulder Elbow Surg*. 2022;31(8): e369-e375.
29. Lade H, McKenzie S, Steele L, Russell TG. Validity and reliability of the assessment and diagnosis of musculoskeletal elbow disorders using telerehabilitation. *J Telemed Telecare*. 2012; 18(7):413-418.
30. Ohta M, Ohira Y, Uehara T, et al. How accurate are first visit diagnoses using synchronous video visits with physicians? *Telemed J E Health*. 2017;23(2):119-129.
31. Trepagnier CG. Virtual environments for the investigation and rehabilitation of cognitive and perceptual impairments. *NeuroRehabilitation*. 1999;12(1):63-72.
32. Lewis JA, Deutsch JE, Burdea G. Usability of the remote console for virtual reality telerehabilitation: formative evaluation. *Cyberpsychol Behav*. 2006;9(2):142-147.
33. Sveistrup H. Motor rehabilitation using virtual reality. *J Neuroeng Rehabil*. 2004;1(1):10.
34. Kayaalp ME, Agres AN, Reichmann J, Bashkuev M, Duda GN, Becker R. Validation of a novel device for the knee monitoring of Orthopaedic patients. *Sensors*. 2019;19(23):5193.
35. Porciuncula F, Roto AV, Kumar D, et al. Wearable movement sensors for rehabilitation: a focused review of technological and clinical advances. *PM R*. 2018;10(9 Suppl 2):S220-S232.
36. Cramer SC, Dodakian L, Le V, et al. A feasibility study of expanded home-based Telerehabilitation after stroke. *Front Neurol*. 2020;11:611453.
37. Borresen A, Chakka K, Wu R, et al. Comparison of In-person and synchronous remote musculoskeletal exam using augmented reality and haptics: a pilot study. *PM&R*. 2022.
38. Asakawa T, Sugiyama K, Nozaki T, et al. Can the latest computerized technologies revolutionize conventional assessment tools and therapies for a neurological disease? The example of Parkinson's disease. *Neurol Med Chir*. 2019;59(3):69-78.
39. Borresen A, Wolfe C, Lin CK, et al. Usability of an immersive augmented reality based Telerehabilitation system with haptics (ARTESH) for synchronous remote musculoskeletal examination. *Int J Telerehabil*. 2019;11(1):23-32.
40. Suso-Marti L, La Touche R, Herranz-Gomez A, Angulo-Diaz-Parreno S, Paris-Alemany A, Cuenca-Martinez F. Effectiveness of Telerehabilitation in physical therapist practice: An umbrella and mapping review with meta-meta-analysis. *Phys Ther*. 2021; 101(5):pzab075.
41. Cottrell MA, Galea OA, O'Leary SP, Hill AJ, Russell TG. Real-time telerehabilitation for the treatment of musculoskeletal conditions is effective and comparable to standard practice: a systematic review and meta-analysis. *Clin Rehabil*. 2017;31(5):625-638.
42. Chen T, Or CK, Chen J. Effects of technology-supported exercise programs on the knee pain, physical function, and quality of life of individuals with knee osteoarthritis and/or chronic knee pain: a systematic review and meta-analysis of randomized controlled trials. *J Am Med Inform Assoc*. 2021;28(2):414-423.
43. Xie SH, Wang Q, Wang LQ, Wang L, Song KP, He CQ. Effect of internet-based rehabilitation programs on improvement of pain and physical function in patients with knee osteoarthritis: systematic review and meta-analysis of randomized controlled trials. *J Med Internet Res*. 2021;23(1):e21542.
44. Agostini M, Moja L, Banzi R, et al. Telerehabilitation and recovery of motor function: a systematic review and meta-analysis. *J Telemed Telecare*. 2015;21(4):202-213.
45. Jiang S, Xiang J, Gao X, Guo K, Liu B. The comparison of telerehabilitation and face-to-face rehabilitation after total knee arthroplasty: a systematic review and meta-analysis. *J Telemed Telecare*. 2018;24(4):257-262.
46. Shukla H, Nair SR, Thakker D. Role of telerehabilitation in patients following total knee arthroplasty: evidence from a systematic literature review and meta-analysis. *J Telemed Telecare*. 2017;23(2):339-346.
47. Wang X, Hunter DJ, Vesentini G, Pozzobon D, Ferreira ML. Technology-assisted rehabilitation following total knee or hip replacement for people with osteoarthritis: a systematic review and meta-analysis. *BMC Musculoskelet Disord*. 2019; 20(1):506.
48. Ibeggazene S, Turner R, Rosario D, Bourke L. Remote interventions to improve exercise behaviour in sedentary people living with and beyond cancer: a systematic review and meta-analysis. *BMC Cancer*. 2021;21(1):308.
49. Tchero H, Tabue Teguo M, Lannuzel A, Rusch E. Telerehabilitation for stroke survivors: systematic review and meta-analysis. *J Med Internet Res*. 2018;20(10):e10867.
50. Laver KE, Adey-Wakeling Z, Crotty M, Lannin NA, George S, Sherrington C. Telerehabilitation services for stroke. *Cochrane Database Syst Rev*. 2020;1:CD010255.
51. Rintala A, Paivarinne V, Hakala S, et al. Effectiveness of technology-based distance physical rehabilitation interventions for improving physical functioning in stroke: a systematic review and meta-analysis of randomized controlled trials. *Arch Phys Med Rehabil*. 2019;100(7):1339-1358.
52. Appleby E, Gill ST, Hayes LK, Walker TL, Walsh M, Kumar S. Effectiveness of telerehabilitation in the management of adults with stroke: a systematic review. *PLoS One*. 2019;14(11): e0225150.
53. Dominguez-Tellez P, Moral-Munoz JA, Casado-Fernandez E, Salazar A, Lucena-Anton D. Effects of virtual reality on balance and gait in stroke: a systematic review and meta-analysis. *Rev Neurol*. 2019;69(6):223-234.
54. Maier M, Rubio Ballester B, Duff A, Duarte Oller E, Verschure P. Effect of specific over nonspecific VR-based rehabilitation on Poststroke motor recovery: a systematic meta-analysis. *Neurorehabil Neural Repair*. 2019;33(2):112-129.
55. Doumas I, Everard G, Dehem S, Lejeune T. Serious games for upper limb rehabilitation after stroke: a meta-analysis. *J Neuroeng Rehabil*. 2021;18(1):100.
56. Cacciante L, Kiper P, Garzon M, et al. Telerehabilitation for people with aphasia: a systematic review and meta-analysis. *J Commun Disord*. 2021;92:106111.
57. Chen J, Jin W, Zhang XX, Xu W, Liu XN, Ren CC. Telerehabilitation approaches for stroke patients: systematic review and meta-analysis of randomized controlled trials. *J Stroke Cerebrovasc Dis*. 2015;24(12):2660-2668.
58. Cacciante L, Pieta CD, Rutkowski S, et al. Cognitive telerehabilitation in neurological patients: systematic review and meta-analysis. *Neurol Sci*. 2022;43(2):847-862.
59. Amatya B, Galea MP, Kesselring J, Khan F. Effectiveness of telerehabilitation interventions in persons with multiple sclerosis: a systematic review. *Mult Scler Relat Disord*. 2015;4(4):358-369.
60. Di Tella S, Pagliari C, Blasi V, Mendozzi L, Rovaris M, Baglio F. Integrated telerehabilitation approach in multiple sclerosis: a systematic review and meta-analysis. *J Telemed Telecare*. 2020;26(7–8):385-399.
61. Rintala A, Hakala S, Paltamaa J, Heinonen A, Karvanen J, Sjogren T. Effectiveness of technology-based distance physical rehabilitation interventions on physical activity and walking in multiple sclerosis: a systematic review and meta-analysis of randomized controlled trials. *Disabil Rehabil*. 2018;40(4): 373-387.
62. Nascimento AS, Fagundes CV, Mendes F, Leal JC. Effectiveness of virtual reality rehabilitation in persons with multiple sclerosis: a systematic review and meta-analysis of randomized controlled trials. *Mult Scler Relat Disord*. 2021;54:103-128.
63. Corti C, Oldrati V, Oprandi MC, et al. Remote technology-based training programs for children with acquired brain injury: a

systematic review and a meta-analytic exploration. *Behav Neurol*. 2019;2019:1346987.
64. Belanger HG, Toyinbo P, Barrett B, King E, Sayer NA. Concussion coach for postconcussive symptoms: a randomized, controlled trial of a smartphone application with Afghanistan and Iraq war veterans. *Clin Neuropsychol*. 2021;1-27:2093-2119.
65. Chrisman SPD, Mendoza JA, Zhou C, et al. Pilot study of telehealth delivered rehabilitative exercise for youth with concussion: the Mobile subthreshold exercise program (MSTEP). *Front Pediatr*. 2021;9:645-814.
66. Ellis MJ, Mendez I, Russell K. Preliminary clinical algorithm to optimise remote delivery of paediatric concussion care in Canada's north. *Int J Circumpolar Health*. 2020;79(1):1832390.
67. Schoenfeld R, Drendel A, Ahamed SI, Thomas D. Longitudinal assessment of acute concussion outcomes through SMS text (ConText study). *Pediatr Emerg Care*. 2022;38(1):e37-e42.
68. Ellis MJ, Boles S, Derksen V, et al. Evaluation of a pilot paediatric concussion telemedicine programme for northern communities in Manitoba. *Int J Circumpolar Health*. 2019;78(1):1573163.
69. Taylor MA, Knochel ML, Proctor SJ, et al. Pediatric trauma telemedicine in a rural state: lessons learned from a 1-year experience. *J Pediatr Surg*. 2021;56(2):385-389.
70. Yurkiewicz IR, Lappan CM, Neely ET, et al. Outcomes from a US military neurology and traumatic brain injury telemedicine program. *Neurology*. 2012;79(12):1237-1243.
71. Caze Ii T, Knell GP, Abt J, Burkhart SO. Management and treatment of concussions via tele-concussion in a pediatric setting: methodological approach and descriptive analysis. *JMIR Pediatr Parent*. 2020;3(2):e19924.
72. Jorgensen-Wagers KCL, Smolinksi G, Cain S. mTBI telehealth in Europe:meeting the geographic challenges with innovative technology and treatment. *Brain Inj*. 2017;31(6–7):856-857.
73. Elbin RJ, Stephenson K, Lipinski D, et al. In-person versus telehealth for concussion clinical care in adolescents: a pilot study of therapeutic alliance and patient satisfaction. *J Head Trauma Rehabil*. 2021;37:213-219.
74. Satin AM, Shenoy K, Sheha ED, et al. Spine patient satisfaction with telemedicine during the COVID-19 pandemic: a cross-sectional study. *Global Spine J*. 2022;12(5):812-819.
75. Fiani B, Siddiqi I, Lee SC, Dhillon L. Telerehabilitation: development, application, and need for increased usage in the COVID-19 era for patients with spinal pathology. *Cureus*. 2020;12(9): e10563.
76. Leung C, Wadhwa H, Sklar M, et al. Telehealth adoption across neurosurgical subspecialties at a single academic institution during the COVID-19 pandemic. *World Neurosurg*. 2021;150:e539-e549.
77. Hobson S, Aleem IS, Bice MJ, et al. A multicenter evaluation of the feasibility, patient/provider satisfaction, and value of virtual spine consultation during the COVID-19 pandemic. *World Neurosurg*. 2021;154:e781-e789.
78. Haddad AF, Burke JF, Mummaneni PV, et al. Telemedicine in neurosurgery: standardizing the spinal physical examination using a modified Delphi method. *Neurospine*. 2021;18(2):292-302.
79. Satin AM, Lieberman IH. The virtual spine examination: telemedicine in the era of COVID-19 and beyond. *Global Spine J*.\ 2021;11(6):966-974.
80. Rothschild B. Telemedicine in musculoskeletal health: adaptations, efficacy, and implications for practice. *HSS J*. 2021;17(3): 360-361.
81. Pujalte G, Loeffert JR, Bertasi TGO, et al. Cervical spine evaluation by telephone and video visit. *Cureus*. 2021;13(11):e19741.
82. Iyer S, Shafi K, Lovecchio F, et al. The spine physical examination using telemedicine: strategies and best practices. *Global Spine J*. 2022;12(1):8-14.
83. Wahezi SE, Duarte RA, Yerra S, et al. Telemedicine during COVID-19 and beyond: a practical guide and best practices multidisciplinary approach for the orthopedic and neurologic pain physical examination. *Pain Physician*. 2020;23(4S):S205-S238.
84. Sardar ZM, Coury JR, Luzzi AJ, Weidenbaum M, Riew KD. The telehealth spine physical examination: a practical approach learned during the COVID-19 pandemic. *World Neurosurg*. 2021;154:e61-e71.
85. Palacin-Marin F, Esteban-Moreno B, Olea N, Herrera-Viedma E, Arroyo-Morales M. Agreement between telerehabilitation and face-to-face clinical outcome assessments for low back pain in primary care. *Spine*. 2013;38(11):947-952.
86. Yoon JW, Welch RL, Alamin T, et al. Remote virtual spinal evaluation in the era of COVID-19. *Int J Spine Surg*. 2020;14(3): 433-440.
87. Jansen T, Gathen M, Touet A, et al. Spine examination during COVID-19 pandemic via video consultation. *Z Orthop Unfall*. 2021;159(2):193-201.
88. Sarig-Bahat H, Weiss PL, Laufer Y. Neck pain assessment in a virtual environment. *Spine*. 2010;35(4):E105-E112.
89. Bhuva S, Lankford C, Patel N, Haddas R. Implementation and patient satisfaction of telemedicine in spine physical medicine and rehabilitation patients during the COVID-19 shutdown. *Am J Phys Med Rehabil*. 2020;99(12):1079-1085.
90. Lightsey HM, Crawford AM, Xiong GX, Schoenfeld AJ, Simpson AK. Surgical plans generated from telemedicine visits are rarely changed after in-person evaluation in spine patients. *Spine J*. 2021;21(3):359-365.
91. Greven ACM, McGinley BM, Nakirikanti AS, et al. Telemedicine in spine surgery: outcomes for 138 patients with virtual preoperative assessment compared to historical controls. *World Neurosurg*. 2022;161:e495-e499.
92. Crawford AM, Lightsey HM, Xiong GX, Striano BM, Schoenfeld AJ, Simpson AK. Telemedicine visits generate accurate surgical plans across orthopaedic subspecialties. *Arch Orthop Trauma Surg*. 2021;142:3009-3016.
93. Crawford AM, Lightsey HM, Xiong GX, et al. Interventional procedure plans generated by telemedicine visits in spine patients are rarely changed after in-person evaluation. *Reg Anesth Pain Med*. 2021;46(6):478-481.
94. Bovonratwet P, Song J, Kim YE, et al. Telemedicine visits can generate highly accurate diagnoses and surgical plans for spine patients. *Spine*. 2022;47(17):1194-1202.
95. Ye IB, Thomson AE, Donahue J, et al. Similar accuracy of surgical plans after initial In-person and telemedicine evaluation of spine patients. *World Neurosurg*. 2022;164:e1043-e1048.
96. Franco D, Montenegro T, Gonzalez GA, et al. Telemedicine for the spine surgeon in the age of COVID-19: multicenter experiences of feasibility and implementation strategies. *Global Spine J*. 2021;11(4):608-613.
97. Cottrell MA, O'Leary SP, Swete-Kelly P, et al. Agreement between telehealth and in-person assessment of patients with chronic musculoskeletal conditions presenting to an advanced-practice physiotherapy screening clinic. *Musculoskelet Sci Pract*. 2018;38:99-105.
98. Shafi K, Lovecchio F, Forston K, et al. The efficacy of telehealth for the treatment of spinal disorders: patient-reported experiences during the COVID-19 pandemic. *HSS J*. 2020;16(Suppl 1):17-23.
99. Bisson LJ, Kluczynski MA, Lindborg CM, et al. The association between patient satisfaction and mode of visit (telemedicine versus in-person) in a large orthopaedic practice during the COVID-19 pandemic lockdown: a retrospective study. *J Am Acad Orthop Surg Glob Res Rev*. 2021;5(9):e21.00046.
100. Greven ACM, McGinley BM, Guisse NF, et al. Telemedicine in the evaluation and Management of Neurosurgical spine patients: questionnaire assessment of 346 consecutive patients. *Spine*. 2021;46(7):472-477.
101. Lightsey HM, Yeung CM, Bernstein DN, et al. Patient experiences of telemedicine in spine care: a mixed methods study. *Spine*. 2022;47(1):27-33.

102. Dario AB, Moreti Cabral A, Almeida L, et al. Effectiveness of telehealth-based interventions in the management of non-specific low back pain: a systematic review with meta-analysis. *Spine J*. 2017;17(9):1342-1351.
103. Mayer JM, Lane CL, Brady O, et al. Comparison of supervised and telehealth delivery of worksite exercise for prevention of low Back pain in firefighters: a cluster randomized trial. *J Occup Environ Med*. 2020;62(10):e586-e592.
104. Vu K, Rhim HC, DeLuca S, Park A, Yun P, Tenforde A. Functional outcomes with telemedicine versus In-person follow-up in patients after Electrocorporeal shockwave therapy. *Clin J Sports Med*. 2022;32(2):226.
105. Hsu C, Eckley C, Tenforde AS. Patient reported functional outcomes of extracorporeal shockwave therapy for overuse tendinopathies through telehealth evaluation during the COVID-19 pandemic. *PM&R*. 2023.
106. Eckley MJ, Hsu C, Tenforde AS. Feasibility using telehealth for planning use of extracorporeal shockwave therapy in a sports medicine clinic. *Healthcare*. 2023;11:1574.
107. Joyce AA, Conger A, McCormick ZL, et al. Changes in interventional pain physician decision-making, practice patterns, and mental health during the early phase of the SARS-CoV-2 global pandemic. *Pain Med*. 2020;21(12):3585-3595.
108. Riew GJ, Lovecchio F, Samartzis D, et al. Telemedicine in spine surgery: global perspectives and practices. Global. *Spine J*. 2021;13:1200-1211.
109. Riew GJ, Lovecchio F, Samartzis D, et al. Spine surgeon perceptions of the challenges and benefits of telemedicine: an international study. *Eur Spine J*. 2021;30(8):2124-2132.
110. Maurer RK, Hallan D, Maurer TC, Lee C, Kelleher JP. Telemedicine in a spine clinic setting: a large survey of patient preferences and experiences. *J Neurosurg Sci*. 2023:351-354.
111. Ye IB, Thomson AE, Chowdhury N, et al. Telemedicine improves access to care for spine patients with low socioeconomic status. *Global Spine J*. 2022;21925682221092398.
112. Cui S, Sedney CL, Daffner SD, et al. Effects of telemedicine triage on efficiency and cost-effectiveness in spinal care. *Spine J*. 2021;21(5):779-784.
113. American Cancer Society. Cancer Facts & Figures. 2022 [cited 2022 March 28].
114. Cheville AL, Mustian K, Winters-Stone K, Zucker DS, Gamble GL, Alfano CM. Cancer rehabilitation: An overview of current need, delivery models, and levels of care. *Phys Med Rehabil Clin N Am*. 2017;28(1):1-17.
115. Stubblefield MD, Schmitz KH, Ness KK. Physical functioning and rehabilitation for the cancer survivor. *Semin Oncol*. 2013;40(6):784-795.
116. Rocque GB, Williams CP, Miller HD, et al. Impact of travel time on health care costs and resource use by phase of Care for Older Patients with Cancer. *J Clin Oncol*. 2019;37(22):1935-1945.
117. ElGohary GM, Hashmi S, Styczynski J, et al. The risk and prognosis of COVID-19 infection in cancer patients: a systematic review and meta-analysis. *Hematol Oncol Stem Cell Ther*. 2020;15:45-53.
118. CDC. Coronavirus Disease 2019 (COVID-19). Centers for Disease Control and Prevention. 2020 [cited 2020 Oct 26]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/index.html
119. Shih KK, Anderson AE, Brown J, et al. Stay home, work safe: attitudes and beliefs of members of a Department of Palliative Care, rehabilitation, and integrative medicine regarding remote work during the COVID-19 pandemic. *J Palliat Med*. 2022;25(5):757-767.
120. Chang PJ, Jay GM, Kalpakjian C, Andrews C, Smith S. Patient and provider-reported satisfaction of Cancer rehabilitation telemedicine visits during the COVID-19 pandemic. *PM R*. 2021;13(12):1362-1368.
121. Lopez CJ, Edwards B, Langelier DM, Chang EK, Chafranskaia A, Jones JM. Delivering virtual Cancer rehabilitation programming during the first 90 days of the COVID-19 pandemic: a multimethod study. *Arch Phys Med Rehabil*. 2021;102(7):1283-1293.
122. Comprehensive Cancer Network National. NCCN Clinical Practice Guidelines in Oncology: Survivorship. 2021 [cited 2022 March 28]. Available from: https://www.nccn.org/professionals/physician_gls/pdf/survivorship.pdf
123. Campbell KL, Winters-Stone KM, Wiskemann J, et al. Exercise guidelines for Cancer survivors: consensus statement from international multidisciplinary roundtable. *Med Sci Sports Exerc*. 2019;51(11):2375-2390.
124. American Cancer Society. American Cancer Society Guideline for Diet and Physical Activity. [cited 2022 March 28]. Available from: https://www.cancer.org/healthy/eat-healthy-get-active/acs-guidelines-nutrition-physical-activity-cancer-prevention/guidelines.html
125. Schrier E, Xiong N, Thompson E, et al. Stepping into survivorship pilot study: harnessing mobile health and principles of behavioral economics to increase physical activity in ovarian cancer survivors. *Gynecol Oncol*. 2021;161(2):581-586.
126. Finley DJ, Stevens CJ, Emond JA, et al. Potential effectiveness of a surgeon-delivered exercise prescription and an activity tracker on pre-operative exercise adherence and aerobic capacity of lung cancer patients. *Surg Oncol*. 2021;37:101525.
127. Piraux E, Caty G, Reychler G, Forget P, Deswysen Y. Feasibility and preliminary effectiveness of a tele-Prehabilitation program in Esophagogastric Cancer patients. *J Clin Med*. 2020;9(7):2176.
128. MacDonald AM, Chafranskaia A, Lopez CJ, et al. CaRE @ home: pilot study of an online multidimensional Cancer rehabilitation and exercise program for Cancer survivors. *J Clin Med*. 2020;9(10):3092.
129. Lafaro KJ, Raz DJ, Kim JY, et al. Pilot study of a telehealth perioperative physical activity intervention for older adults with cancer and their caregivers. *Support Care Cancer*. 2020;28(8):3867-3876.
130. Ji W, Kwon H, Lee S, et al. Mobile health management platform-based pulmonary rehabilitation for patients with non-small cell lung Cancer: prospective clinical trial. *JMIR Mhealth Uhealth*. 2019;7(6):e12645.
131. Coats V, Moffet H, Simard S, et al. Home-based telerehabilitation program using real-time monitoring and interactive exercise for patient with lung cancer: a feasibility study. *Eur Respir J*. 2015;46:OA3283.
132. Ligibel JA, Partridge A, Giobbie-Hurder A, et al. Physical and psychological outcomes among women in a telephone-based exercise intervention during adjuvant therapy for early stage breast cancer. *J Womens Health*. 2010;19(8):1553-1559.
133. Granger CL, Irving L, Antippa P, et al. CAPACITY: a physical activity self-management program for patients undergoing surgery for lung cancer, a phase I feasibility study. *Lung Cancer*. 2018;124:102-109.
134. Loh KP, Sanapala C, Watson EE, et al. A single-arm pilot study of a mobile health exercise intervention (GO-EXCAP) in older patients with myeloid neoplasms. *Blood Adv*. 2022;6(13):3850-3860.
135. Sagarra-Romero L, Butragueno J, Gomez-Bruton A, Lozano-Berges G, Vicente-Rodriguez G, Morales JS. Effects of an online home-based exercise intervention on breast cancer survivors during COVID-19 lockdown: a feasibility study. *Support Care Cancer*. 2022;30(7):6287-6297.
136. Gorzelitz JS, Stoller S, Costanzo E, et al. Improvements in strength and agility measures of functional fitness following a telehealth-delivered home-based exercise intervention in endometrial cancer survivors. *Support Care Cancer*. 2022;30(1):447-455.
137. Lozano-Lozano M, Martin-Martin L, Galiano-Castillo N, et al. Mobile health and supervised rehabilitation versus mobile health

alone in breast cancer survivors: randomized controlled trial. *Ann Phys Rehabil Med*. 2020;63(4):316-324.
138. Ariza-Garcia A, Lozano-Lozano M, Galiano-Castillo N, Postigo-Martin P, Arroyo-Morales M, Cantarero-Villanueva I. A web-based exercise system (e-CuidateChemo) to counter the side effects of chemotherapy in patients with breast Cancer: randomized controlled trial. *J Med Internet Res*. 2019;21(7):e14418.
139. Uhm KE, Yoo JS, Chung SH, et al. Effects of exercise intervention in breast cancer patients: is mobile health (mHealth) with pedometer more effective than conventional program using brochure? *Breast Cancer Res Treat*. 2017;161(3):443-452.
140. Kanera IM, Willems RA, Bolman CA, Mesters I, Verboon P, Lechner L. Long-term effects of a web-based cancer aftercare intervention on moderate physical activity and vegetable consumption among early cancer survivors: a randomized controlled trial. *Int J Behav Nutr Phys Act*. 2017;14(1):19.
141. Galiano-Castillo N, Cantarero-Villanueva I, Fernandez-Lao C, et al. Telehealth system: a randomized controlled trial evaluating the impact of an internet-based exercise intervention on quality of life, pain, muscle strength, and fatigue in breast cancer survivors. *Cancer*. 2016;122(20):3166-3174.
142. Morrison KS, Paterson C, Toohey K. The feasibility of exercise interventions delivered via telehealth for people affected by Cancer: a rapid review of the literature. *Semin Oncol Nurs*. 2020;36(6):151092.
143. Haberlin C, O'Dwyer T, Mockler D, Moran J, O'Donnell DM, Broderick J. The use of eHealth to promote physical activity in cancer survivors: a systematic review. *Support Care Cancer*. 2018;26(10):3323-3336.
144. Burton M, Valet M, Caty G, Aboubakar F, Reychler G. Telerehabilitation physical exercise for patients with lung cancer through the course of their disease: a systematic review. *J Telemed Telecare*. 2022;1357633X221094200.
145. Dietzen A, Ide W, Pavone L. Telehealth in pediatric rehabilitation medicine: a survey of clinician reported utilization and experience. *J Pediatr Rehabil Med*. 2020;13(3):281-288.
146. Davidson L, Haynes SC, Favila-Meza A, et al. Parent experience and cost savings associated with a novel tele-physiatry program for children living in rural and underserved communities. *Arch Phys Med Rehabil*. 2022;103(1):8-13.
147. Irgens I, Rekand T, Arora M, et al. Telehealth for people with spinal cord injury: a narrative review. *Spinal Cord*. 2018;56(7):643-655.
148. Touchett H, Apodaca C, Siddiqui S, et al. Current approaches in telehealth and Telerehabilitation for spinal cord injury (TeleSCI). *Curr Phys Med Rehabil Rep*. 2022;10(2):77-88.
149. Olszewski C, Thomson S, Strauss L, et al. Patient experiences with ambulatory telehealth in neurology: results of a mixed-methods study. *Neurol Clin Pract*. 2021;11(6):484-496.
150. Krumholz HM. Post-Hospital Syndrome—an acquired, transient condition of generalized risk. *N Engl J Med*. 2013;368(2):100-102.
151. Covinsky KE, Pierluissi E, Johnston CB. Hospitalization-associated disability: "she was probably able to ambulate, but I'm not sure". *JAMA*. 2011;306(16):1782-1793.
152. Forman DE, Arena R, Boxer R, et al. Prioritizing functional capacity as a principal end point for therapies oriented to older adults with cardiovascular disease: a scientific statement for healthcare professionals from the American Heart Association. *Circulation*. 2017;135(16):e894-e918.
153. Fulmer T, Berman A. Age-friendly health systems: how do we get there? 2016 [cited 2022 April 1]. Available from: http://healthaffairs.org/blog/2016/11/03/age-friendly-health-systems-how-do-we-get-there/
154. Fulmer T, Mate KS, Berman A. The age-friendly health system imperative. *J Am Geriatr Soc*. 2018;66(1):22-24.
155. Mate K, Fulmer T, Pelton L, et al. Evidence for the 4Ms: interactions and outcomes across the care continuum. *J Aging Health*. 2021;33(7–8):469-481.
156. Palmer RM. The acute care for elders unit model of care. *Geriatrics*. 2018;3(3):59.
157. Livingston G, Huntley J, Sommerlad A, et al. Dementia prevention, intervention, and care: 2020 report of the lancet commission. *Lancet*. 2020;396(10248):413-446.
158. Fulmer T, Reuben DB, Auerbach J, Fick DM, Galambos C, Johnson KS. Actualizing better health and health care for older adults. *Health Aff*. 2021;40(2):219-225.
159. Ross R, Blair SN, Arena R, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement from the American Heart Association. *Circulation*. 2016;134(24):e653-e699.
160. Morley JE, Vellas B, van Kan GA, et al. Frailty consensus: a call to action. *J Am Med Dir Assoc*. 2013;14(6):392-397.
161. Dent E, Lien C, Lim WS, et al. The Asia-Pacific clinical practice guidelines for the Management of Frailty. *J Am Med Dir Assoc*. 2017;18(7):564-575.
162. Barone Gibbs B, Hivert MF, Jerome GJ, et al. Physical activity as a critical component of first-line treatment for elevated blood pressure or cholesterol: who, what, and how?: a scientific statement from the American Heart Association. *Hypertension*. 2021;78(2):e26-e37.
163. Batalik L, Dosbaba F, Hartman M, Konecny V, Batalikova K, Spinar J. Long-term exercise effects after cardiac telerehabilitation in patients with coronary artery disease: 1-year follow-up results of the randomized study. *Eur J Phys Rehabil Med*. 2021;57(5):807-814.
164. *Crossing the quality chasm: a new health system for the 21st century*. Washington (DC). 2001.
165. Guiding principles for the care of older adults with multimorbidity: an approach for clinians. Guiding principles for the care of older adults with multimorbidity: an approach for clinicians: American Geriatrics Society expert panel on the Care of Older Adults with multimorbidity. *J Am Geriatr Soc*. 2012;60(10):E1-E25.
166. Fried LP, Cohen AA, Xue QL, Walston J, Bandeen-Roche K, Varadhan R. The physical frailty syndrome as a transition from homeostatic symphony to cacophony. *Nat Aging*. 2021;1(1):36-46.
167. Brouwers RWM, van der Poort EKJ, Kemps HMC, van den Akker-van Marle ME, Kraal JJ. Cost-effectiveness of cardiac Telerehabilitation with relapse prevention for the treatment of patients with coronary artery disease in The Netherlands. *JAMA Netw Open*. 2021;4(12):e2136652.
168. Dalli Peydro E, Sanz Sevilla N, Tuzon Segarra MT, Miro Palau V, Sanchez Torrijos J, Cosin SJ. A randomized controlled clinical trial of cardiac telerehabilitation with a prolonged mobile care monitoring strategy after an acute coronary syndrome. *Clin Cardiol*. 2022;45(1):31-41.
169. Snoek JA, Prescott EI, van der Velde AE, et al. Effectiveness of home-based Mobile guided cardiac rehabilitation as alternative strategy for nonparticipation in clinic-based cardiac rehabilitation among elderly patients in Europe: a randomized clinical trial. *JAMA Cardiol*. 2021;6(4):463-468.
170. Thomas RJ, Beatty AL, Beckie TM, et al. Home-based cardiac rehabilitation: a scientific statement from the American Association of Cardiovascular and Pulmonary Rehabilitation, the American Heart Association, and the American College of Cardiology. *Circulation*. 2019;140(1):e69-e89.
171. Su J, Zhang Y, Ke QQ, Su JK, Yang QH. Mobilizing artificial intelligence to cardiac telerehabilitation. *Rev Cardiovasc Med*. 2022;23(2):45.
172. Rockwood K, Song X, MacKnight C, et al. A global clinical measure of fitness and frailty in elderly people. *CMAJ*. 2005;173(5):489-495.
173. Juma S, Taabazuing MM, Montero-Odasso M. Clinical frailty scale in an acute medicine unit: a simple tool that predicts length of stay. *Can Geriatr J*. 2016;19(2):34-39.

174. O'Neill D, Forman DE. Never too old for cardiac rehabilitation. *Clin Geriatr Med*. 2019;35(4):407-421.
175. Kahlon S, Pederson J, Majumdar SR, et al. Association between frailty and 30-day outcomes after discharge from hospital. *CMAJ*. 2015;187(11):799-804.
176. Chang JE, Lai AY, Gupta A, Nguyen AM, Berry CA, Shelley DR. Rapid transition to telehealth and the digital divide: implications for primary care access and equity in a post-COVID era. *Milbank Q*. 2021;99(2):340-368.
177. Verma A, Towfighi A, Brown A, Abhat A, Casillas A. Moving towards equity with digital health innovations for stroke care. *Stroke*. 2022;53(3):689-697.
178. Budhwani S, Fujioka J, Thomas-Jacques T, et al. Challenges and strategies for promoting health equity in virtual care: findings and policy directions from a scoping review of reviews. *J Am Med Inform Assoc*. 2022;29(5):990-999.
179. Alexander M. The day for tomorrow. *J Climate Change and Health*. 2021;4:100062.
180. Blom IM, Beagley J, Quintana AV. The COP26 health commitments: a springboard towards environmentally sustainable and climate-resilient health care systems? *J Climate Change and Health*. 2022;6:100136.
181. Holmner A, Ebi KL, Lazuardi L, Nilsson M. Carbon footprint of telemedicine solutions–unexplored opportunity for reducing carbon emissions in the health sector. *PLoS One*. 2014;9(9): e105040.
182. Vidal-Alaball J, Franch-Parella J, Lopez Segui F, Garcia Cuyas F, Mendioroz PJ. Impact of a telemedicine program on the reduction in the emission of atmospheric pollutants and journeys by road. *Int J Environ Res Public Health*. 2019;16(22): 4366.
183. Bartlett S, Keir S. Calculating the carbon footprint of a geriatric medicine clinic before and after COVID-19. *Age Ageing*. 2022; 51(2):afab275.
184. Thota R, Gill DM, Brant JL, Yeatman TJ, Haslem DS. Telehealth is a sustainable population health strategy to lower costs and increase quality of health care in Rural Utah. *JCO Oncol Pract*. 2020;16(7):e557-e562.
185. Blenkinsop S, Foley A, Schneider N, Willis J, Fowler HJ, Sisodiya SM. Carbon emission savings and short-term health care impacts from telemedicine: an evaluation in epilepsy. *Epilepsia*. 2021;62(11):2732-2740.
186. Evers EC, Fritz SA, Colditz GA, Burnham JP. Perceptions of telemedicine and costs incurred by a visit to a general infectious diseases clinic: a survey. *Open Forum Infect Dis*. 2022;9(3): ofab661.
187. Whetten J, Montoya J, Yonas H. ACCESS to better health and clear skies: telemedicine and greenhouse gas reduction. *Telemed J E Health*. 2019;25(10):960-965.
188. Dullet NW, Geraghty EM, Kaufman T, et al. Impact of a university-based outpatient telemedicine program on time savings, travel costs, and environmental pollutants. *Value Health*. 2017;20(4):542-546.
189. Robinson JD, Prochaska JD, Yngve DA. Pre-surgery evaluations by telephone decrease travel and cost for families of children with cerebral palsy. *SAGE Open Med*. 2017;5: 2050312117720046.
190. Dacones I, Cave C, Furie G, Ogden C, Slutzman J. Patient transport greenhouse gas emissions from outpatient care at an integrated health care system in the northwestern United States, 2015–2020. *J Climate Change and Health*. 2021;3:100024.
191. Iaccarino MA, Paganoni S, Tenforde A, et al. Environmental impacts of Telerehabilitation in an urban setting. *J Climate Change and Health*. 2022;8:100150.
192. Kouis P, Papatheodorou SI, Kakkoura MG, et al. The MEDEA childhood asthma study design for mitigation of desert dust health effects: implementation of novel methods for assessment of air pollution exposure and lessons learned. *BMC Pediatr*. 2021;21(1):13.
193. Durieux ME. "Primum non Nocere": global health and climate change. *Anesth Analg*. 2020;131(3):981-983.
194. Duhaime A, Futernick M, Alexander M, et al. Healthcare professionals need to be CCLEAR: climate collaborators, leaders, educators, advocates, and researchers. *J Climate Change and Health*. 2021;4:100078.

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