Effectiveness of tele-rehabilitation programs in elderly with hip osteoarthritis: a scoping review

Nawel Ouendi[1,2], Eugénie Avril[1], Benjamin Dervaux[2], Philippe Pudlo[1], Laura Wallard[1*]
[1]Université Polytechnique Hauts-de-France, CNRS, UMR 8201 – LAMIH – Laboratoire d'Automatique de Mécanique et d'Informatique Industrielles et Humaines, F-59313 Valenciennes, France
[2]Pôle SSR – Maison Sport Santé – Institut Jean Stablinski, Centre Hospitalier de Valenciennes, France
*Laura.Wallard @uphf.fr

Abstract:
Background: Hip osteoarthritis generates very often musculoskeletal pain causing functional impairment and decreasing mobility, autonomy and quality of life. Patients are then often offered specific telerehabilitation care to provide them with the possibility to practice painless and supervised adapted physical and functional activities. But what about effectiveness of these telerehabilitation programs? **Objectives**: The aim of this scoping review is to list and highlight different telerehabilitation currently offered during hip OA care in order to assess their effectiveness in programs care. **Methods**: 5 databases were screened for "osteoarthritis", "hip osteoarthritis", "pre-operation", "rehabilitation", "tele-rehabilitation", "digital health", "telecommunication" in accordance with PRISMA-ScR guideline. **Results**: 19 articles were selected according to inclusion criteria. The telerehablitation was offered in 6 different ways (video call, applications smartphones, website, etc.). The assessments were mainly quality of life questionnaires, the perceived effort after exercises, field surveys on the tool experience, physical tests to assess motor functions and interviews to measure acceptability before use. **Conclusion**: This review highlights the importance and relevance to evaluate contributions and limitations of new healthcare technologies in order to improve patient follow-up and thus enable better remote clinical care.

Keywords: Hip osteoarthritis, osteoarthritis, New information and communication technologies, e-health, tele-rehabilitation

I. INTRODUCTION

Osteoarthritis (OA) is the most common joint disease, affecting about 240 million people worldwide, including more than 10 million in France [1], becoming a major public health problem [2]. According to INSERM (2022), 10% of cases in France are affected by coxarthrosis. Hip OA is characterised by a progressive degeneration of joint that affects cartilage, bone, and periarticular soft tissues [1]. Several studies have showed that hip OA is characterised by severe musculoskeletal pain and limitation of articular movement gradually decreasing autonomy and quality of life of OA patients. Pain and stiffness directly impact mobility and the ability to be physically active [6-8]. Indeed, the hip OA impacts negatively the functional activity and the global mobility of the patient. For exemple, the gait is then illustrated by abnormal patterns [9-12] associated with a reduced walking speed [13-14], a reduction of the hip muscle strength [9, 15-16] and higher cardiac and energetic costs of gait [13-14] relative to asymptomatic adults. (e.g. walking, climbing stairs) [6,11-14]. Patients with hip OA are commonly prescribed exercise-based rehabilitation programs that focus on reducing pain and improving physical function [15-18].

In recent years, and with the deployment of public health budget strategies, new information and communication technologies (NTIC) are increasingly used in the monitoringand clinical care of patients, especially in pre- and postoperative orthopaedic management. These new e-health devices are indeed proving to be a relevant solution for a distance care of people with reduced mobility [19]. Indeed, the term e-health, with its equivalents: telehealth, digital health, connected health, refers to all areas where TICs are used for health purposes [20]. General sense, digital health is defined as the use of digital information, data and communications to collect and analyse health information to improve patient care and health and the delivery of care [21-30]. Moreover, digital health tends to reduce costs for therapists and patients and offers a health service to patients living in rural areas who have, for example, difficulties in moving around (reduced mobility, medical desertification, geographical isolation, etc.) [31-41].

In the rehabilitation context, these new practices are based in particular on the principles of telecommunication, and more specifically on tele-rehabilitation [42]. Tele-rehabilitation can be defined as a creative way of providing rehabilitation services from a distance using a wide variety of devices such as smartphones, digital tablets, videoconferencing, specific applications, embedded virtual reality, data transmission by video and photos or by electronic message sent by the health care provider and/or the patient [36,43,44]. The usefulness of digital devices in the short- and medium-term follow-up of neurological patients [45] or post orthopaedic surgery patients [46] has been demonstrated. Indeed, the use of NTICs by patients has been shown to improve cognitive function in patients with multiple sclerosis [47-50], and to be more available and accessible than with conventional methods. Furthermore, it has been shown that assessments by face-to-face professionals compared to tele-rehabilitation provided the same results [51], with similar clinical outcomes on pain care, fatigue, motor function, physical activity assessments between traditional and tele-rehabilitation [52-56].

However, many technological and societal barriers remain and limit the deployment of tele-rehabilitation. For example, the devices used to deliver therapeutic services (e.g., smartphone or digital tablet with applications) are unfortunately currently not sufficiently adapted and flexible to be delivered from a distance, which reduces their use and especially the engagement of patient and clinician users.

The aim of this scoping review is to highlight the technological used in digital health over the last 10 years in patients with pre-operative hip OA, more particularly in the tele-rehabilitation care.

II. METHODS

A. *Protocol*

This scoping review was performed according to the PRISMA-ScR (Preffered Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews) [57].

B. *Search strategy and article selection*

This scoping review search was carried out using the following electronic data bases: MEDLINE, PubMed, Scopus, PEDro and Web of sciences; and using a combination of keywords related to « "osteoarthritis", "hip osteoarthritis", "pre-operation", "rehabilitation", "tele-rehabilitation", "digital health", "telecommunication". The search strategy was between the years 2013 to 2023, namely over 10 years.
Only publications in which the participants were seniors adults and elderly (40-80 years) with hip OA were included. Other eligibility criteria were: observational or experimental studies (e.g. randomised controlled trials, before/after studies), articles published in English. The articles were excluded if they were not available as full text commentaries or conference abstracts, or if the patients had undergone hip replacement surgery / hip arthroplasty. The exclusion criteria were: not complete articles, study of patients with OA other than the hip and those, although, there is the use of telecommunication tools, studies on patients with hip arthroplasty, patients under 40 years (Fig.1).

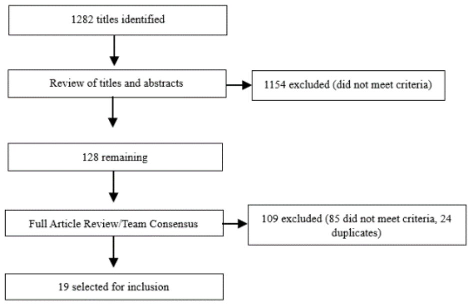

Figure 1. Flow Diagram.

C. *Data extraction and analyses*

The research on the various databases was carried out by a member of the research team (NO). Any duplications were removed with the software *Zotero*. Titles and abstracts were then reviewed by two independent members (NO and LW) of the research team, based on the inclusion and exclusion criteria (Fig.1). For all studies that met our inclusion criteria, the full text was retrieved, analyzed and evaluated by the same two authors. Any conflict was resolved by discussion.
For all publications meeting the inclusion criteria, two authors (NO and LW) independently extracted information using PICOT criteria (Table I). These criteria consist of five points: Population (P), Intervention (I), Comparison (C), Outcomes (O), Temporality (T).

Table I. PICOT criteria.

Population	Elderly with hip osteoarthritis
Intervention	Therapeutic and clinical care with NTICs, implementation of physical activities programs with NTICs
Comparison	e.g., conventional therapies vs. therapies with NTICs, only NTICs (before-after care)
Outcomes	e.g., clinical evaluations (questionnaires, scores, mobility and activity scales, etc.), user feedback (satisfaction questionnaires)
Temporality	pre-surgery, before stade 4 of hip OA or before hip arthroplasty.

All extracted information was validated between the two authors (NO and LW) confirming that the data extracted was accurate and complete. Studies presenting the results from the same group of participants were considered a single study and the results were extracted together.
In order to assess the relevance of proposed therapies for telereadaptation in elderly with hip OA, the following variables were extracted.

Self-report measures of function assessment: Western Ontario and McMaster (WOMAC index) [58], [60], [64], [71], [72],Hip and Osteoarthritis Outcome Score (HOOS) [62],[63],[68],[69],[71],[74],[75],[76], Assessment of Quality of Life (AQoL) [60], [65], [68], [69], [71], [74], Visual Analogic Scales (VAS – Pain) [58], [60], [62], [65], [66], [67], [68], [71], [72], [76], Arthritis Self-Efficacy Scale (ASES) [60], [68],Physical Activity Scale for the Elderly (PASE) [60], [62].

Functional Tests: test 30 chair stand test (30CST) [65], [67], [71], [72], [73]. Short Physical Performance Battery (SPPB) [72], Senior Fitness Test (SFT) [72], Number of steps with accelerometer wrist [58], [69],[73], on hip [68].

Telerehabilitation assessment: semi-structured interviews assessing acceptability and acceptance face-to-face or virtually interviews with content analysis. Characteristics and indicators of the studies were collected and analysed. [65], [75], System Usability Scale (SUS) [63], [68], [74], The Telemedicine Perception Questionnaire (TMPQ) [59], [70].

D. Study validity assessment

Two authors (NO and LW) independently analysed the methodological quality of each study using the Newcastle-Ottawa scale for non-randomised controlled trials (n=6) and cohort studies (n=1) (Table IIa) and finally the PEDro scale for randomised controlled trials (n=11) (Table IIb). For the Newcastle-Ottawa scale, each study could obtain a maximum of nine stars: 4 stars for study group selection, 1 star for group comparability and 3 stars for exposure or outcome of interest. For the randomised crossover studies included in this scoping review, the PEDro scale was used. This tool consists of 11 questions that are answered with "yes" or "no", with a higher number of "yes" answers representing a better reliability of the article.

III. RESULTS

A. Search results

The electronic database search produced 128 publications for the selection. Twenty-four duplicates were removed from the selection using *Zotero*, leaving 104 articles to be processed (Fig. 1).

Of the 104 articles, 85 were excluded because they did not meet the inclusion criteria: either the study only involved patients with knee OA, or the patients had undergone arthroplasty, or they did not correspond to the themes of our aim study. Articles with a focus on digital health in general have been removed from the selection. In summary, 19 articles [58-76] were processed in full text (Fig. 1).

Of the 19 articles included (Fig. 2), 5 from the Netherlands [62], [63], [64], [69], [74] (i.e. 26%), 4 from Sweden [65], [66], [67], [73] (i.e. 21%), 3 from Australia [59], [60], [70] (i.e. 16%), 2 from Norway [68], [71] (i.e. 11%), 2 from the USA [58], [75] (i.e. 11%), and 1 from Chile [72] (i.e. 5%), from Germany [76], from Italy [61].

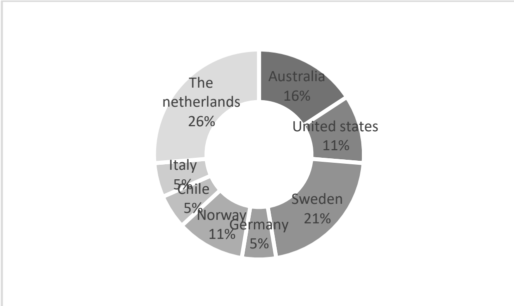

Figure 2. Distribution of articles in the countries.

Fourteen of the selected articles were research articles (i.e. 74% of the selected articles), 5 were research protocols (i.e. 21%), and 1 was a short paper of 4 pages (i.e. 5%).

Of the 19 selected articles, all were about hip OA and digital health monitoring for patients aged between 40 and 80 years depending on the study. The sample size also varied from 19 to 330 users. From the point of view of study characteristics, 5 were observational studies, and 14 were interventions or experimental studies. Different means of communication were used: video calls with professional and video exercices (n=8) [65-67], [69], [70], [72], [73], [75] applications (n=4) [71], [73], [74], [76], website (n=10) [58], [60], [62-69] phone calls (n=3) [58], [65], [70], social networks (n=2) [65], [72], emails (n=6) [58], [63-67]. As we can see above, in some studies more than one means of communication was used by the researchers (Fig. 3).

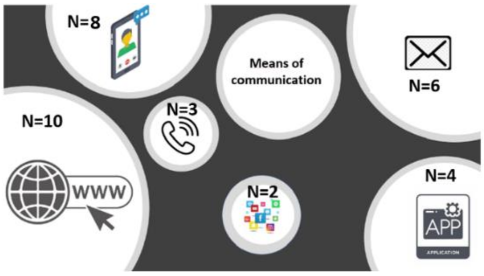

Figure 3. The different means of communication used.

B. Intervention

The selected articles show that physical exercise have been implemented in different ways. For example, [58], [60], [62], [63], [68] used explanatory cards with a representation of the exercises that could be printed out by the patients; [65], [66], [67], [69], [72], [73], [75] used explanatory videos for the implementation of a PA program. Others, such as [71], used text, audio and video instructions for each exercise in their program. In addition to providing a library of textual exercise information, [74] used a "small habit method", e.g. "after lunch, I get up from my chair 12 times to train my leg muscles".

The exercise program were mainly based on functional/balance exercises (i.e., standing weight transfers, one-legged stance), muscle strengthening (i.e., hip abduction, i.e., hip extensors, i.e., quadriceps) and stretching/flexibility (i.e., standing hip flexors), and exercises such as seated knee extension, partial squats, isometric partial wall squats, sit-to-stand, etc.

The evaluation questionnaires on their perception of effort or pain after performing the exercises were offered to patients in order to assess their physical feelings. Moreover, the evaluation of the motor function, the reduction of pain in patients, the improvement of the quality of life or the evaluation of the acceptability and feasibility of a digital monitoring program were proposed in their clinical care follow-up. All the variables analyzed are explained and illustrated in the methodology section.

C. *Evaluations*

The (Fig.4) shows us that 15 studies used self-report measures of function such as questionnaires or scales [58], [60], [62], [65], [66], [67], [68], [69], [71], [72], [73], [74], [76].
Eight studies used functional tests [58], [65], [67], [68], [69], [71], [72], [73]. And finally, 7 studies used assessments of tele-rehabilitation through interviews, or questionnaires as well [59], [63], [65], [68], [70], [74], [75].
Indeed, as we can see some studies have used several assessments in their methods.[58], [60], [62], [65], [66], [67], [68], [69], [71], [72], [73], [74].

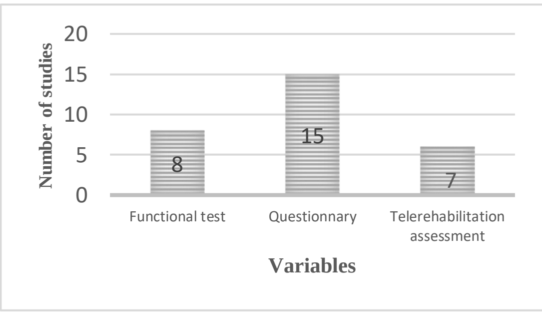

Figure 4. Variables and assessments implemented.

Eight [60], [62], [63], [64], [65], [69], [72], [73], [76] studies used a protocol with a control group and an experimental group, 6 studies [58], [66], [67], [68], [71], [74], compared outcomes within a single group. The aim of studies was either to assess the acceptance and feasibility of implementing a follow-up program in patients (n=4) [59], [68], [70], [75] and, a study [61] to inform the implementation of telemedicine in people with hip OA. (Fig.5).

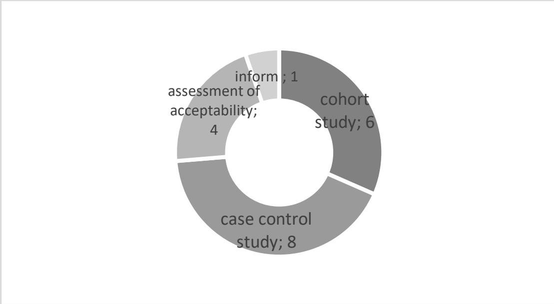

Figure 5. Pie chart representing the distribution of items.

As mentioned in the methodology section, quality assessment scales for the articles were made. These scales illustrate the methodological quality of the studies set up.
The Newcastle Ottawa Scale (Table IIa) results show that 3 articles [59], [70], [75] have 5 stars. One article [66] has 6 stars. And finally, 3 articles have 7 stars [58], [67], [68].

TABLE IIa: Methodological appraisal of studies with Newcastle-Ottawa Scale – quality assessment scale for no-randomized controlled trials.

References	Selection				Comparability	Exposure			Total
	Crit.1	Crit.2	Crit.3	Crit.4	Crit.1	Crit.1	Crit.2	Crit.3	
[58] Allen et al., 2020	X	X	-	X	X	X	X	X	7
[59] Lawford et al., 2017	-	-	X	X	X	-	X	X	5
[66] Dahlberg et al., 2016	-	X	X	X	X	-	X	X	6
[67] Dahlberg et al., 2020 (cohort study)	X	X	-	X	X	X	X	X	7
[68] Joseph et al., 2022	X	X	-	X	X	X	X	X	7
[70] Lawford et al., 2017	X	X	-	X	X	-	X	X	5
[75] Stern et al., 2022	-	X	X	X	X	-	X	-	5

Moreover, according to PEDro scale (Table IIb), one article [74] is at level 5, 4 articles at level 6 [65], [71], [73], [76], 3 articles had a level 7 [62], [63], [72], and finally 3 articles with a score of 8 [60], [64], [69].

TABLE IIb: Methodological assessment of studies with the PEDro scale - a scale for assessing the quality of randomised controlled trials.

References	Crit. 1	Crit. 2	Crit. 3	Crit. 4	Crit. 5	Crit. 6	Crit. 7	Crit. 8	Crit. 9	Crit. 10	Crit. 11	TOTAL
[60] Bennell et al., 2015	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	8
[62] Bossen et al., 2013	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
[63] Bossen et al., 2013	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
[64] Claassen et al., 2020	Y	N	Y	Y	Y	Y	Y	N	Y	Y	N	8
[65] Cronström et al., 2019	Y	N	Y	Y	N	N	N	N	Y	Y	Y	6
[69] Kloek et al., 2018	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	8
[71] Martinsen et al., 2022	Y	N	Y	Y	N	N	N	N	Y	Y	Y	6
[72] Munoz-Fonseca et al., 2022	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7
[73] Östlind et al., 2022	Y	Y	N	Y	N	N	N	N	Y	Y	Y	6
[74] Pelle et al., 2021	Y	N	Y	N	N	N	N	N	Y	Y	Y	5
[76] Strahl et al., 2022	Y	Y	Y	Y	N	N	N	N	N	Y	Y	6

Finally, a comparison between the means of communication used in the articles (cf. tele-rehabilitation, tele-consulting, etc.) and the evaluation scores of the Newcastle Ottawa Scale and PEDro scales, the results show that the care quality is higher for those that used a method of communication with textual and/or graphs exchanges on the physical activity program.

IV. CONCLUSION AND PERSPECTIVES

The aim of this scoping review was to highlight the technologies used in the field of digital health over the last ten years in patients with hip OA, more particularly in the context of tele-rehabilitation care. Indeed, our scoping review shows that the majority of articles (12 out of 19, i.e. 60%) [58], [60], [63], [64], [66], [67], [68], [69], [71], [72], [74], [75] from a distance assessed symptoms, motor function and quality of life due to hip OA. In addition, these studies used many of the same variables, including the assessment questionnary which measures fatigue, pain, and quality of life.

The questionnaires used (WOMAC, HOOS, EuroQol, etc.) are recommended by the International Consortium for Health Outcomes Measurement to allow a standard assessment, based on biopsychosocial approach as the use of International Classification of Functioning, Disabil-ity and Health model [79]. Namely, the main objective of these questionnaires in research is to obtain relevant information in the most reliable and valid way [80].

In 2016, [81] proved to us that rehabilitation in orthopaedics has been defined as any non-pharmacological or non-surgical intervention aimed at improving symptoms (pain, deformity, stiffness), motor function and/or quality of life.

The results of the studies seem to be consistent with other authors, such as [82] where the authors showed that technologies can provide exercise therapy, encourage adherence to physical activity [83] and support distance rehabilitation [84,85].Moreover, these results are confirmed by some authors [71] have stated that distance monitoring programming is more comprehensive as a complement to conventional therapy.Furthermore, some studies [70] have shown that distance monitoring allows a reduction in intervention and medication costs, compared to usual therapy.

Despite the positive results and the potential acceptability of TICs by patients in the articles included, some limitations remain in the literature. Indeed, the complexity of integrating technology into rehabilitation interventions and research has been highlighted by these authors [86]. According to them, it may be useful to consider that in most situations, individual technologies are used as a mechanism to deliver, promote or monitor the active ingredient (i.e. exercise therapy) in an intervention. It will also be essential to find ways to monitor and improve the fidelity of interventions and/or implementation. Moreover, it is important to recognize that technological aids may be less appropriate in lower socio-economic communities unless they can be adapted to the local context.

These contexts pose rise to numerous problems in terms of ergonomics (e.g., interface ergonomics), use (centred on the adaptation of clinical and rehabilitation care towards patient autonomy) and finally, the reduction of social diversification (e.g., short-, medium- and long-term follow-up care). These problems must therefore be assessed and characterized specifically to propose digital devices adapted and in line with the demands of users (patients and clinicians).

In conclusion, our study was able to provide a summary of the effective care of patients with preoperative hip OA using biomedical devices and digital health technologies. This work highlights the importance and relevance to evaluate the contributions and limitations of new health technologies in order to improve future patient follow-up and thus enable recommended standard care. This also highlights the importance of considering the needs of users by adopting a user-centric approachce when designing new health technologies. Indeed, it seems relevant to us that future studies be based in particular on specific models such as the model of the International Classification of Functioning, Disability and Health [85], used as a guide for setting rehabilitation objectives, planning interventions and follow-up; but also ergonomic analysis models used to quantify user needs.

REFERENCES

[1] Katz, J. N., Arant, K. R., & Loeser, R. F. (2021). Diagnosis and treatment of hip and knee osteoarthritis: a review. *Jama*, *325*(6), 568-578

[2] Klussmann, A., Gebhardt, H., Nübling, M., Liebers, F., Quirós Perea, E., Cordier, W., ... & Rieger, M. A. (2010). Individual and occupational risk factors for knee osteoarthritis: results of a case-control study in Germany. *Arthritis research & therapy*, *12*(3), 1-15.

[3] Zacharias, A. ; Pizzari, T.; anglais, DJ ; Kapakoulakis, T.; Vert, RA Volume du muscle abducteur de la hanche dans la coxarthrose et contrôles correspondants. Ostéoarthr. Chariot. 2016, 24, 1727–1735.

[4] Loureiro, A.; Moulins, PM ; Barrett, RS Faiblesse musculaire dans l'arthrose de la hanche : Une revue systématique. Soins de l'arthrite Res. 2013, 65, 340–352

[5] Marshall, AR ; Noronha, MD; Zacharias, A.; Kapakoulakis, T.; Green, R. Structure et fonction des abducteurs chez les patients atteints d' arthrose de la hanche : examen systématique et méta-analyse. J. Dos musculosquelettique. Réhabilit. 2016, 29, 191–204.

[6] Pua YH, Wrigley TW, Cowan SM, Bennell KL. Intrarater test-retest reliability of hip range of motion and hip muscle strength measurements in persons with hip osteoarthritis. Arch Phys Med Rehabil 2008; 89(6): 1146-54.

[7] Steultjens MP, Dekker J, Van Baar ME, Oostendorp RA, Bijlsma JW. Range of joint motion and disability in patients with osteoarthritis of the knee or hip. Rheumatol 2000; 39(9): 955-61.

[8] Winter CC, Brandes M, Muller C, Schubert T, Ringling M, Hillman A, et al. Walking ability during daily life in patients with osteoarthritis of the knee or the hip and lumbar spinal stenosis: a cross sectional study. BMC Musculoskelet Disord 2010; 11: 233.

[9] Eitzen I, Fernandes L, Nordsletten L, Risberg MA. Sagittal plane gait characteristics in hip osteoarthritis patients with mild to moderate symptoms compared to healthy controls: a cross-sectional study. BMC Musculoskelet Disord 2012; 13: 258.

[10] Foucher KC, Schlink BR, Shakoor N, Wimmer MA. Sagittal plane hip motion reversals during walking are associated with disease severity and poorer function in subjects with hip osteoarthritis. J Biomech 2012; 45(8): 1360-5.

[11] Wallard, L., Cornu, O., Dubuc, J-E., Mahaudens, P., Postlethwaite, D., Vancauter, M. & Detrembleur, C. (201*Computer Methods in Biomechanics and Biomedical Engineering, 20 (1), 207-9.*

[12] Wallard, L., Boulet, S., Cornu, O., Dubuc, J-E., Mahaudens, P., Postlethwaite, D., Vancauter, M. & Detrembleur, C. (2018) Intersegmental kinematics coordination in unilateral peripheral and central origin: effect on gait mechanism? *Gait & Posture,* 62, 124-31

[13] Schepens SL, Kratz AL, Murphy SL. Fatigability in osteoarthritis: effects of an activity bout on subsequent symptoms and activity. J Gerontol A Biol Med Sci 2012; 67: 1114-20..

[14] Schmitt D, Vap A, Queen RM. Effect of end-stage hip, knee, and ankle osteoarthritis on walking mechanics. Gait Posture 2015; 42: 373-9.

[15] Constantinou M, Barrett R, Brown M, Mills P. Spatial-temporal gait characteristics in individuals with hip osteoarthritis: a systematic literature review and meta-analysis. J Orthop Sports Phys Ther 2014; 44(4): 291-7.

[16] Foucher KC, Hurwitz DE, Wimmer MA. Preoperative gait adaptations persist one year after surgery in clinically well-functioning total hip replacement patients. J Biomech 2007; 40(15): 3432-7.

[17] Othman, OA ; van der Windt, DA; Jordan, JL; Dziedzic, KS ; Healey, EL; Tourbe, GM ; Foster, NE Exercice pour l'arthrose des membres inférieurs : examen systématique incorporant une analyse séquentielle des essais et une méta-analyse en réseau. BMJ 2013, 347, f5555.

[18] Allen, K., Vu, M. B., Callahan, L. F., Cleveland, R. J., Gilbert, A. L., Golightly, Y. M., ... & Wandishin, A. E. (2020). Osteoarthritis physical activity care pathway (OA-PCP): results of a feasibility trial. *BMC Musculoskeletal Disorders*, *21*(1), 1-11.

[19] Peretti, A., Amenta, F., Tayebati, S. K., Nittari, G., & Mahdi, S. S. (2017). Telerehabilitation: review of the-state-of-the-art and areas of application. *JMIR rehabilitation and assistive technologies*, *4*(2), e7511.

[20] Safon, M.-O., La e-santé Télésanté, santé numérique ou santé connectée, IRDES, 2018, en ligne.

[21] Turakhia MP, Desai SA, Harrington RA. The outlook of digital health for cardiovascular medicine: challenges but also extraordinary opportunities. JAMA Cardiol 2016;1:743–4.

[22] Rock Health. Digital health funding 2017 midyear review: a record breaking first half. Rock Health web site.

[23] The Economist. The truly personal computer. The Economist web site.

[24] Beam AL, Kohane IS. Translating artificial intelligence into clinical care. JAMA 2016;316:2368–9

[25] Gulshan V, Peng L, Coram M, et al. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA 2016;316:2402–10.

[26] Wong TY, Bressler NM. Artificial intelligence with deep learning technology looks into diabetic retinopathy screening. JAMA 2016;316:2366–7.

[27] BlueStar. BlueStar web site. http://www.bluestardiabetes.com. Accessed September 1, 2017.

[28] Syed ST, Gerber BS, Sharp LK. Traveling towards disease: transportation barriers to health care access. J Community Health 2013;38:976–93.

[29] Powers BW, Rinefort S, Jain SH. Nonemergency medical transportation: delivering care in the era of Lyft and Uber. JAMA 2016;316:921–2.

[30] Topol E. The Patient Will See You Now: The Future of Medicine is in Your Hands. New York, NY: Basic Books; 2015.

[31] Amatya, B., Galea, M.P., Kesselring, J. et Khan, F. (2015). Le ou les auteurs n'ont déclaré aucun conflit d'intérêts potentiel en ce qui concerne la recherche, la paternité et/ou la publication de cet article. Efficacité des interventions de téléréadaptation chez les personnes atteintes de sclérose en plaques : une revue systématique. Sclérose en plaques et troubles apparentés, 4(4), 358–369.

[32] Block, VAJ, Pitsch, E., Tahir, P., Cree, BAC, Allen, DD et Gelfand, JM (2016). Surveillance à distance de l'activité physique dans les maladies neurologiques : une revue systématique.

[33] Dorstyn, D., Mathias, J. et Denson, L. (2013). Applications du télécounselling dans la réadaptation des lésions de la moelle épinière : une revue systématique avec des tailles d'effet. Réadaptation clinique, 27(12), 1072–1083.

[34] Huang, K., Liu, W., He, D., Huang, B., Xiao, D., Peng, Y., Huang, D. (2015). Interventions de télésanté par rapport à la réadaptation cardiaque en centre de la maladie coronarienne : une revue systématique et une méta-analyse. Journal européen de cardiologie préventive, 22(8), 959–971.

[35] Johansson, T., & Wild, C. (2011). Téléréadaptation dans les soins de l'AVC : une revue systématique. Journal de télémédecine et de télésoins, 17(1), 1–6.

[36] Kairy, D., Lehoux, P., Vincent, C., & Visintin, M. (2009). Une revue systématique des résultats cliniques, du processus clinique, de l'utilisation des soins de santé et des coûts associés à la téléréadaptation

[37] Khan, F., Amatya, B., Kesselring, J. et Galea, M. (2015) Téléréadaptation pour les personnes atteintes de sclérose en plaques. La base de données Cochrane des revues systématiques, 4. Extrait de

[38] Rogante, M., Grigioni, M., Cordella, D., & Giacomozzi, C. (2010). Dix ans de téléréadaptation : un aperçu de la littérature sur les technologies et les applications cliniques. Neuroréhabilitation, 27(4), 287–304.

[39] Santos, MTND, Moura, SCDO, Gomes, LMX, Lima, AH, Moreira, RS, Silva, CD et Guimaraes, EMP (2014). Application de télésanté sur la rééducation des enfants et des adolescents. Revista Paulista de Pédiatrie, 32(1), 136–143.

[40] Cason, J. (2014). Télésanté : Un modèle de prestation de services en développement rapide pour l'ergothérapie. Journal international de téléréadaptation, 6(1), 29–35.

[41] Cason, J. (2012). Possibilités de télésanté en ergothérapie grâce à la Loi sur les soins abordables. Journal américain d'ergothérapie, 66, 131–136.

[42] Zampolini, M., Todeschini, E., Hermens, H., Ilsbroukx, S., Macellari, V., Magni, R., ... & Giacomozzi, C. (2008). Tele-rehabilitation: present and future. *Annali dell'Istituto superiore di sanita*, *44*(2), 125-134.

[43] Brennan D., Tindall, L., Theodoros D., Brown, J., Campbell, M., Christiana, D., Smith, D., Lee, A. (2010). Un plan directeur pour les directives de téléréadaptation. Journal international de téléréadaptation, 2(2), 31–34.

[44] McCue, M., Fairman, A. et Pramuka, M. (2010). Améliorer la qualité de vie grâce à la téléréadaptation. Cliniques de médecine physique et de réadaptation d'Amérique du Nord, 21(1), 195–205.

[45] Remy et al. (2020) Telecommunication and rehabilitation among patients with multiple sclerosis: access and willingness to use. European Journal of Physical and Rehabilitation Medicine, 56(4): 403-11.

[46] Fascio et al. (2022) Early virtual-reality-based home rehabilitation after total hip arthroplasty: a randomized controlled trial. Journal of Clinical Medicine 11, 1766, 1-12.

[47] Wicks P, Massagli M, Kulkarni A, Dastani H. Use of an online community to develop patient-reported outcome instruments: the Multiple Sclerosis Treatment Adherence Questionnaire (MS-TAQ). J Med Internet Res 2011;13(1):e12 [FREE Full text] [doi: 10.2196/jmir.1687] [Medline: 21266318]

[48] Goverover Y, O'Brien AR, Moore NB, DeLuca J. Actual reality: a new approach to functional assessment in persons with multiple sclerosis. Arch Phys Med Rehabil 2010 Feb;91(2):252-260. [doi: 10.1016/j.apmr.2009.09.022] [Medline: 20159130]

[49] Negreiros MA, Mattos P, Landeira-Fernandez J, Paes RA, Alvarenga RP. A brief neuropsychological screening test battery for cognitive dysfunction in Brazilian multiple sclerosis patients. Brain Inj 2008 May;22(5):419-426. [doi: 10.1080/02699050801998243] [Medline: 18415722]

[50] Younes M, Hill J, Quinless J, Kilduff M, Peng B, Cook SD, et al. Internet-based cognitive testing in multiple sclerosis. Mult Scler 2007 Sep;13(8):1011-1019. [doi: 10.1177/1352458507077626] [Medline: 17623730]

[51] Biebl, J. T., Rykala, M., Strobel, M., Kaur Bollinger, P., Ulm, B., Kraft, E., ... & Lorenz, A. (2021). App-based feedback for rehabilitation exercise correction in patients with knee or hip osteoarthritis: prospective cohort study. *Journal of Medical Internet Research*, *23*(7), e26658.

[52] McKeon, JF ; Alvarez, PM ; Vajapey, AS ; Sarac, N.; Spitzer, IA ; Vajapey, SP Élargir le rôle de la technologie dans la réadaptation Après le remplacement de l'articulation des membres inférieurs : une revue systématique. JBJS Rév. 2021, 9, e21. [Référence croisée]

[53] Agostini, M. ; Moja, L.; Banzi, R.; Pistotti, V.; Tonin, P. ; Venneri, A.; Turolla, A. Télérééducation et récupération de la fonction motrice : A revue systématique et méta-analyse. J. Telemed. Télésoins 2015, 21, 202–213. [Référence croisée]

[54] Cottrell, MA; Galéa, OA ; O'Leary, SP; Colline, AJ ; Russell, TG La téléréadaptation en temps réel pour le traitement des affections musculo-squelettiques est efficace et comparable à la pratique standard : une revue systématique et une méta-analyse. Clin. Réhabilit. 2017, 31, 625–638

[55] Shukla, H. ; Nair, S.; Thakker, D. Rôle de la téléréadaptation chez les patients après une arthroplastie totale du genou : preuves d'une revue systématique de la littérature et d'une méta-analyse. J. Telemed. Télésoins 2017, 23, 339–346.

[56] Wang, Q. ; Lee, RL; Hunter, S.; Chan, SW L'efficacité de la téléréadaptation sur Internet chez les patients après une arthroplastie totale de l'articulation : une revue systématique et une méta-analyse d'essais contrôlés randomisés. J. Telemed. Téléassistance 2021, 1357633X20980291.

[57] Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., ... & Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Annals of internal medicine*, *169*(7), 467-473.

[58] Allen, K., Vu, M. B., Callahan, L. F., Cleveland, R. J., Gilbert, A. L., Golightly, Y. M., ... & Wandishin, A. E. (2020). Osteoarthritis physical activity care pathway (OA-PCP): results of a feasibility trial. *BMC Musculoskeletal Disorders*, *21*(1), 1-11.

[59] Lawford, B. J., Bennell, K. L., Kasza, J., & Hinman, R. S. (2018). Physical therapists' perceptions of telephone-and internet video–mediated service models for exercise management of people with osteoarthritis. *Arthritis care & research*, *70*(3), 398-408.

[60] Bennell, K. L., Rini, C., Keefe, F., French, S., Nelligan, R., Kasza, J., ... & Hinman, R. S. (2015). Effects of adding an internet-based pain coping skills training protocol to a standardized education and exercise program for people with persistent hip pain (HOPE trial): randomized controlled trial protocol. *Physical therapy*, *95*(10), 1408-1422.

[61] Bernetti, A., Farì, G., Mangone, M., Fiore, P., Santilli, V., Paoloni, M., & Agostini, F. (2022). SHORT PAPER Medical management of osteoarthritis during the CO-VID-19 pandemic: a challenge for the present and the future. *Ann Ig*, *34*(2), 184-189.

[62] Bossen, D., Veenhof, C., Van Beek, K. E., Spreeuwenberg, P. M., Dekker, J., & De Bakker, D. H. (2013). Effectiveness of a web-based physical activity intervention in patients with knee and/or hip osteoarthritis: randomized controlled trial. *Journal of medical Internet research*, *15*(11), e2662.

[63] Bossen, D., Veenhof, C., Dekker, J., & de Bakker, D. (2013). The usability and preliminary effectiveness of a web-based physical activity intervention in patients with knee and/or hip osteoarthritis. *BMC medical informatics and decision making*, *13*(1), 1-8.

[64] Claassen, A. A., Schers, H. J., Busch, V. J., Heesterbeek, P. J., van den Hoogen, F. H., Vliet Vlieland, T. P., & van den Ende, C. H. (2020). Preparing for an orthopedic consultation using an eHealth tool: a randomized controlled trial in patients with hip and knee osteoarthritis. *BMC Medical Informatics and Decision Making*, *20*(1), 1-10.

[65] Cronström, A., Dahlberg, L. E., Nero, H., Ericson, J., & Hammarlund, C. S. (2019). 'I would never have done it if it hadn't been digital': a qualitative study on patients' experiences of a digital management programme for hip and knee osteoarthritis in Sweden. *BMJ open*, *9*(5), e028388.

[66] Dahlberg, L. E., Grahn, D., Dahlberg, J. E., & Thorstensson, C. A. (2016). A web-based platform for patients with osteoarthritis of the hip and knee: a pilot study. *JMIR research protocols*, *5*(2), e5665.

[67] Dahlberg, L. E., Dell'Isola, A., Lohmander, L. S., & Nero, H. (2020). Improving osteoarthritis care by digital means-

Effects of a digital self-management program after 24-or 48-weeks of treatment. *PLoS One*, *15*(3), e0229783.

[68] Jönsson, T., Eek, F., Hansson, E. E., Dahlberg, L. E., & Dell'Isola, A. (2023). Factors associated with clinically relevant pain reduction after a self-management program including education and exercise for people with knee and/or hip osteoarthritis: Data from the BOA register. *Plos one*, *18*(2), e0282169.

[69] Joseph, K. L., Dagfinrud, H., Hagen, K. B., Nordén, K. R., Fongen, C., Wold, O. M., ... & Tveter, A. T. (2022). The AktiWeb study: feasibility of a web-based exercise program delivered by a patient organisation to patients with hip and/or knee osteoarthritis. *Pilot and Feasibility Studies*, *8*(1), 150.

[70] Kloek, C. J., Van Dongen, J. M., De Bakker, D. H., Bossen, D., Dekker, J., & Veenhof, C. (2018). Cost-effectiveness of a blended physiotherapy intervention compared to usual physiotherapy in patients with hip and/or knee osteoarthritis: a cluster randomized controlled trial. *BMC Public Health*, *18*, 1-12.

[71] Lawford, B. J., Bennell, K. L., & Hinman, R. S. (2017). Consumer perceptions of and willingness to use remotely delivered service models for exercise management of knee and hip osteoarthritis: A cross-sectional survey. *Arthritis Care & Research*, *69*(5), 667-676.

[72] Martinsen, L., Østerås, N., Moseng, T., & Tveter, A. T. (2022). Effect of a mHealth exercise intervention compared with supervised exercise therapy in osteoarthritis management: protocol of the DigiOA trial. *BMJ open*, *12*(9), e066248.

[73] Muñoz-Fonseca, F., Concha-Cisternas, Y., Díaz-Martínez, X., Celis-Morales, C., Zapata-Lamana, R., & Cigarroa, I. (2022). Efectos en la capacidad funcional de un programa de ejercicio físico terapéutico basado en telesalud en personas con diagnóstico de osteoartritis de rodilla y cadera. *Revista médica de Chile*, *150*(1), 33-45.

[74] Östlind, E., Ekvall Hansson, E., Eek, F., & Stigmar, K. (2022). Experiences of activity monitoring and perceptions of digital support among working individuals with hip and knee osteoarthritis–a focus group study. *BMC Public Health*, *22*(1), 1-11.

[75] Pelle, T., van der Palen, J., de Graaf, F., van den Hoogen, F. H., Bevers, K., & van den Ende, C. H. (2021). Use and usability of the dr. Bart app and its relation with health care utilisation and clinical outcomes in people with knee and/or hip osteoarthritis. *BMC health services research*, *21*, 1-10.

[76] Saragiotto, B. T., Fioratti, I., Deveza, L., Yamato, T. P., Richards, B. L., Maher, C. G., ... & Costa, L. O. (2020). Telerehabilitation for hip or knee osteoarthritis. *The Cochrane Database of Systematic Reviews*, *2020*(6).

[77] Stern, B. Z., Pila, S., Joseph, L. I., Rothrock, N. E., & Franklin, P. D. (2022). Patients' perspectives on the benefits of feedback on patient-reported outcome measures in a web-based personalized decision report for hip and knee osteoarthritis. *BMC Musculoskeletal Disorders*, *23*(1), 806.

[78] Strahl, A., Graichen, H., Haas, H., Hube, R., Perka, C., Rolvien, T., & Hubert, J. (2022). Evaluation of the patient-accompanying app "alley ortho companion" for patients with osteoarthritis of the knee and hip: study protocol for a randomized controlled multi-center trial. *Trials*, *23*(1), 1-13.

[79] World Health Organisation. Int Classif Funct, Disab Health. Geneva: WHO, 2021

[80] Taherdoost, H. (2016). Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in research. *How to test the validation of a questionnaire/survey in research (August 10, 2016)*.

[81] Whittaker, J. L., Truong, L. K., Dhiman, K., & Beck, C. (2021). Osteoarthritis year in review 2020: rehabilitation and outcomes. *Osteoarthritis and cartilage*, *29*(2), 190-207.

[82] Lin, Y. T., Lee, W. C., & Hsieh, R. L. (2020). Active video games for knee osteoarthritis improve mobility but not WOMAC score: A randomized controlled trial. *Annals of Physical and Rehabilitation Medicine*, *63*(6), 458-465.

[83] Baker, K., LaValley, M. P., Brown, C., Felson, D. T., Ledingham, A., & Keysor, J. J. (2020). Efficacy of Computer-Based Telephone Counseling on Long-Term Adherence to Strength Training in Elderly Patients With Knee Osteoarthritis: A Randomized Trial. *Arthritis care & research*, *72*(7), 982-990.

[84] Hinman, R. S., Campbell, P. K., Lawford, B. J., Briggs, A. M., Gale, J., Bills, C., ... & Bennell, K. L. (2020). Does telephone-delivered exercise advice and support by physiotherapists improve pain and/or function in people with knee osteoarthritis? Telecare randomised controlled trial. *British journal of sports medicine*, *54*(13), 790-797.

[85] Sykes, C. (2006). Health classifications 1–an introduction to the ICF. *London: WCPTKeynotes*