J Rehabil Med 2021; 53: jrm00155

SPECIAL REPORT

CONTRIBUTION OF THE SCIENTIFIC FIELD OF PHYSICAL AND REHABILITATION MEDICINE TO IMPROVEMENTS IN HEALTH-RELATED REHABILITATION AT ALL LEVELS OF THE HEALTHCARE SYSTEM: A DISCUSSION PAPER

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Rehabilitation is an important health strategy that should be implemented at all levels of the healthcare system and at all levels of care. Scientific evidence is vital to strengthen rehabilitation; therefore, research in the scientific field of Physical and Rehabilitation Medicine (PRM) should be implemented and linked to all levels of the healthcare system. PRM research can be categorized into 5 areas: (*i*) biosciences in rehabilitation; (*ii*) biomedical rehabilitation sciences and engineering; (*iii*) clinical PRM sciences; (*iv*) integrative rehabilitation sciences; and (*v*) human functioning sciences. At the level of the healthcare system, rehabilitation can be divided into micro-, meso- and macro-levels. This paper discusses the contribution of the five above research areas to health-related rehabilitation at the different levels of the healthcare system. The contribution of PRM research can have synergistic value and facilitate improvements and implementation of scientific evidence in rehabilitation at all levels of healthcare. From a broader perspective, improved understanding of the contribution of each area of the scientific field of PRM and the priorities for the healthcare system that are set by relevant stakeholders will contribute to the advancement and rapid attainment of overall goals.

Key words: rehabilitation; scientific field; health system; physical and rehabilitation medicine.

Accepted Oct 28, 2020; Epub ahead of print Nov 30, 2020

J Rehabil Med 2021; 53: jrm00155

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LAY ABSTRACT

Rehabilitation leads to better health, participation, and quality of life of persons with chronic disease or impairment. It should be part of health care at all levels. In order to implement rehabilitation services, it is important to create a scientific basis. Science in the field of rehabilitation includes studies on mechanisms of disease and healing process, the effects of the application of treatments on the body, the effectiveness of therapy as well as the implementation of rehabilitation projects, and the theoretical basis. The results of such work are helpful to implement and optimize rehabilitation in clinical work and in health policies. The goal is that every person who needs rehabilitation will have access to quality rehabilitation services.

The global prevalence of health conditions has shifted to an increase in non-communicable health conditions, which include ageing, metabolic syndromes, severe health conditions (e.g. cancer), and injury. These can lead to increased issues regarding functioning.

The World Health Organization (WHO) addresses the management of this global issue in their publications. The *Global Disability Action Plan* (GDAP), 2014 (1), set out 3 major aims: (*i*) to remove barriers and improve access to health services and programmes; (*ii*) to strengthen and extend rehabilitation, habilitation, assistive technology, assistance and support services, and community-based rehabilitation; and (*iii*) to strengthen the collection of relevant and internationally comparable data on disability and support research on disability and related services. The GDAP includes proposal inputs for the member states to improve rehabilitation and success indicators. The document *Rehabilitation in Health Systems*, 2017 (2), sets out recommendations for governments and stakeholders to strengthen and expand rehabilitation. This document is based on scientific evidence; however, evidence to support the recommendations needs to be further improved at all levels of the healthcare system.

Research can provide scientific evidence to improve all fields, including rehabilitation. Since rehabilitation comprises a large area of medicine, the aim of this paper is to demonstrate the contribution of the different areas of Physical and Rehabilitation Medicine (PRM) research (3) to rehabilitation in the healthcare system (4). This will facilitate understanding of the contribution of the scientific field of PRM to improvements in rehabilitation, demonstrate synergistic value, and facilitate improvements in rehabilitation at all levels of the healthcare system. From a broader perspective, improved understanding of the contribution of each area of the scientific field of PRM, and how they relate to the priorities of healthcare systems designed by the relevant stakeholders, will contribute to the advancement and rapid attainment of the overall goals of the rehabilitation.

DEFINITION OF REHABILITATION

The term "rehabilitation" is often misunderstood or used in a broader sense than originally intended.

doi: 10.2340/16501977-2773

Rehabilitation is often thought of as treatment after surgery or trauma and during palliative care. This understanding is not fully incorrect; however, it leads to a misconception of rehabilitation. The definition of rehabilitation has been formulated by experts and included in the *World Report on Disability,* as "a set of measures that assist individuals who experience, or are likely to experience, disability to achieve and maintain optimal functioning in interaction with their environments" (5). However, rehabilitation is also a health strategy, which is "based on WHO's integrative model of functioning, disability and health (ICF) that applies and integrates approaches to assess functioning, optimize a person's capacity, strengthen the resources of the person, and provide a facilitating environment, with the goal to enable persons with health conditions experiencing or likely to experience disability to achieve and maintain optimal functioning in interaction with their environment" (6). There are other definitions of rehabilitation, but they all agree that rehabilitation aims to achieve and maintain optimal functioning. Since environmental factors also play a role in addition to the field of medicine, other stakeholders should also be involved in order to achieve this goal.

REHABILITATION IN THE HEALTHCARE SYSTEM

As stated above, rehabilitation can be defined both as a health strategy and as a set of interventions/measures. Reflecting on these definitions, rehabilitation should be integrated into all levels of the healthcare system: micro-, meso- and macro-levels.

Rehabilitation at the micro-level. Rehabilitation at the micro-level includes rehabilitation programmes for specific health conditions (e.g. stroke, cancer). However, rehabilitation should also be implemented both at the level of healthcare (primary, secondary, and tertiary levels of healthcare services) and throughout healthcare services (habilitation, pre-habilitation, acute, post-acute and long term rehabilitation) (Fig. 1). Pre-habilitation is defined as an educational programme and pre-operative physical and/or psychological conditioning, enhancing functional and mental capacity aimed at improving postoperative functional outcomes (7). Rehabilitation at the micro-level works directly to provide the best intervention for the patient. Although large studies of rehabilitation programmes have been conducted, improvements are needed to increase efficiency and outcomes for patients' needs.

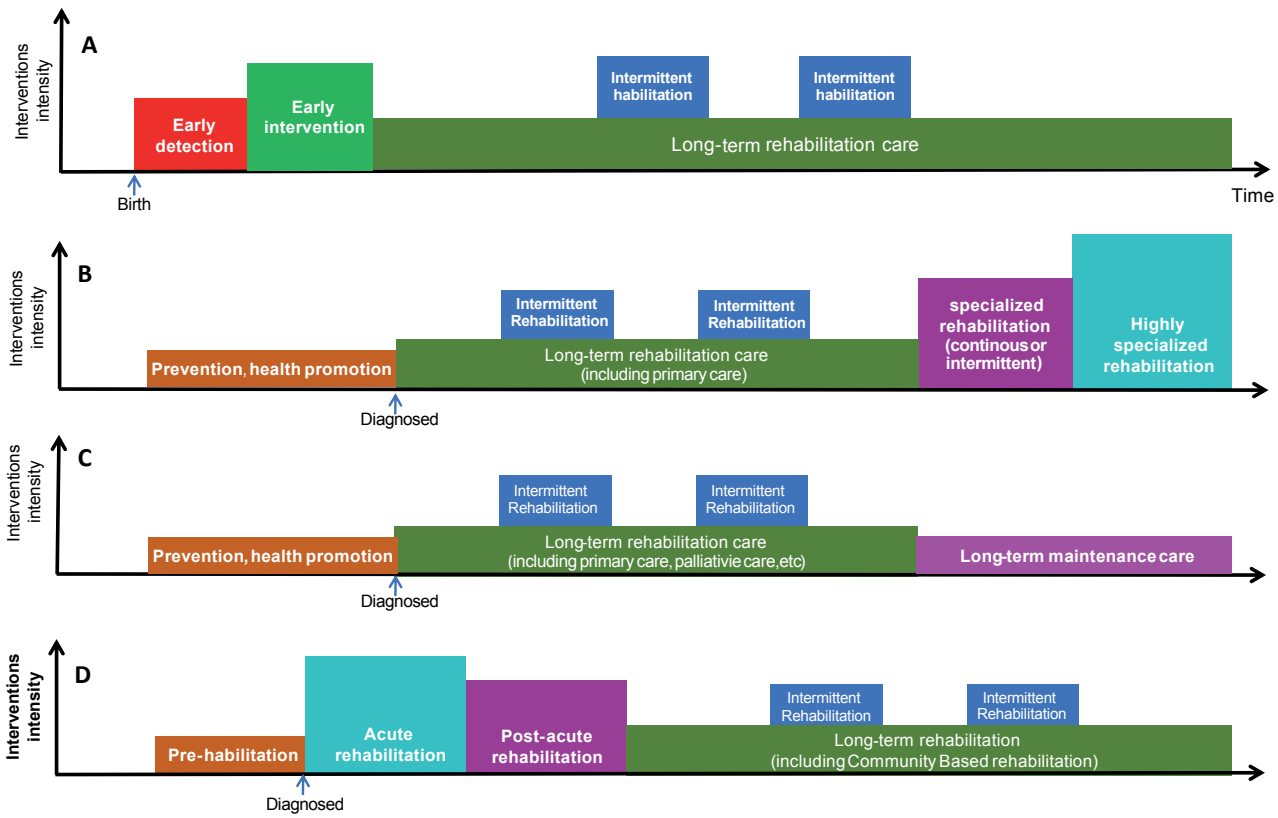

Fig. 1. (A) Phases of rehabilitation service provision for congenital diseases/disability; (B) chronic progressive diseases; (C) chronic non-progressive diseases; (D) after acute incidents.

Rehabilitation at the meso-level. Rehabilitation at the meso-level includes the healthcare workforce providing rehabilitation services and the rehabilitation service organization itself (8). Interestingly, due to the nature of rehabilitation, most treatments will be more effective and provide better outcomes if rehabilitation is delivered by multiprofessional teams (including PRM specialist, physiotherapist, occupational therapist, psychotherapist or psychologist, orthotist and prosthetist, rehabilitation nurse, community based-rehabilitation worker, etc.) (8).

Rehabilitation service organization varies worldwide; for example, it may comprise a single profession or multiprofessional teams; and rehabilitation equipment may range from simple to advanced, depending on the context, type and level of rehabilitation services. Al though this variation could provide the flexibility to organize rehabilitation services even in rural areas, it also requires minimum standards to describe rehabilitation service organization in order to achieve optimal functioning for people in need. A group of researchers have therefore proposed a classification to describe rehabilitation service organization; the International Classification of Service Organization in Rehabilitation (ICSO-R) (8). The ICSO-R consists of 3 dimensions: provider, funding, and service delivery. Each dimension has several categories. A second version of the ICSO-R (ICSO-R 2.0 (9)) has been developed after testing, implementing and receiving comments from international experts. The ICSO-R 2.0 comprises only 2 dimensions; provider and service delivery, as the funding dimension has been distributed into each of these dimensions.

The ICSO-R classification can be used in various ways: to describe rehabilitation service organization; to support situation analysis of the provision of rehabilitation services in healthcare systems at the national or provincial level and to prototype the service (10, 11); to develop recommendations for implementation of rehabilitation services (11); for quality management in rehabilitation services (12); and to describe the setting in clinical trials, which may have a strong influence on rehabilitation outcomes. Thus, the ICSO-R is a useful tool for many purposes; however, further research into its implementation is necessary.

Rehabilitation at the macro-level. Rehabilitation is 1 of 5 health strategies, together with curative, preventive, palliative and supportive strategies. Therefore rehabilitation should be explicitly mentioned and implemented within the healthcare system in every country.

To support the strengthening of rehabilitation at the healthcare system level, WHO has formulated a rehabilitation support package (13) to enable countries to strengthen rehabilitation in the healthcare system. The package starts by analysing rehabilitation in the healthcare system, then enables recommendations, project implementation, evaluation and monitoring.

Other activities related to strengthening rehabilitation in healthcare systems have been reported: in Egypt (14), Ukraine (15) and the Democratic People's Republic of Korea (16). These 3 activities use sounding methodology (17), including collecting information related to rehabilitation at the country level, using a rehabilitation service assessment tool (11), site visits, analysis of gaps, and listing and prioritizing recommendations and projects for improvement (10).

PHYSICAL AND REHABILITATION MEDICINE RESEARCH

Rehabilitation has been proposed as a health strategy for the 21st century (18). Improvements in rehabilitation at all levels of the healthcare system are urgently needed in order to increase the unmet need for rehabilitation worldwide. However, this development must not neglect the quality of rehabilitation itself. Scientific evidence is therefore important to support improvements in the rehabilitation field at all levels of the healthcare system.

The scientific field of PRM is relatively large. Other fields of medicine focus mainly on specific bodily systems, but this is not the case for PRM, which is based on the bio-psycho-social model of functioning and disability, and can be divided into 5 areas, according to the WHO International Classification of Functioning, Disability and Health (ICF) (19) (see Fig. 2). These areas are:

- *Biosciences in rehabilitation.* "The biosciences, the basic sciences from the partial perspective based on the biomedical model of disease (3). This area aim to explain body injury, adaptation and repair from the molecular to the cellular, organ system and organism level; and to identify targets for biomedical interventions to improve body functions and structures" "(21).
- *Biomedical rehabilitation sciences and engineering.* "These refer to the partial perspective interested in the biomedical aspect of functioning can be called biomedical rehabilitation sciences and engineering (3). The Biomedical rehabilitation sciences and engineering are applied sciences that study diagnostic measures and interventions including physical modalities suitable to minimize impairment, control symptoms and to optimize people's capacity", robotic as well as nanotechnology for rehabilitation intervention. (21).
- *Clinical PRM sciences.* This field aims to provide the best care in PRM (3). It has goal to enabling

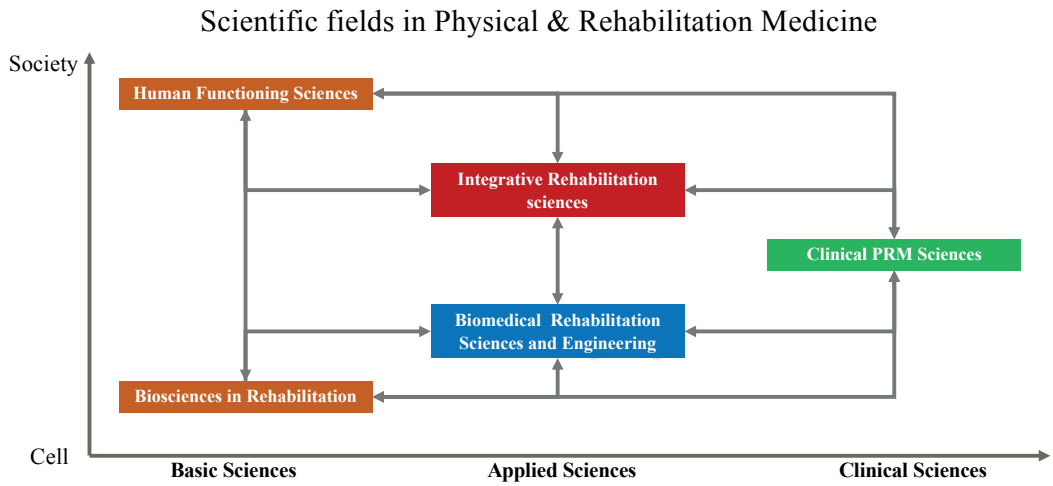

Fig. 2. From cell to society (Stucki and Grimby (3) (2007), modified). PRM: Physical and Rehabilitation Medicine.

people with health conditions experiencing or likely to experience disability to achieve and maintain optimal functioning in interaction with their immediate environment. Clinical research in rehabilitation is one example. The outcome from this study including efficiency, clinical guidelines, and standards, quality management, education and training of professional rehabilitation" (21).

- *Integrative rehabilitation sciences.* Integrative rehabilitation sciences design and study of rehabilitation systems, services, comprehensive assessments, and intervention programmes, which integrate biomedical, personal and environmental factor approaches to optimize people's performance (21).
- *Human functioning sciences.* "Human functioning sciences aim to understand human functioning and to identify targets for comprehensive interventions" (21). Human functioning sciences contribute to the minimization of the experience of disability in the population.

Gutenbrunner et al. (20) elaborated categories based on this concept and developed a topic list. The topic list was applied to structure scientific program at the ISPRM World Congresses in 2015 (Berlin) and 2016 (Kuala Lumpur). A subsequent revision of congress topic list was published, based on analyses from both congresses (21) (see topic list in Table I).

Table I. Short topic list of the scientific field of Physical and Rehabilitation Medicine (PRM) (for a more detailed explanation see Nugraha et al. (21))

A. Clinical PRM Sciences
A.1. Pain
A.2. Musculoskeletal conditions
A.3. Health conditions of the nervous system
A.4. Mental health conditions
A.5. Internal medicine and related conditions
A.6. Post-surgery and post-traumatic rehabilitation
A.7. Rehabilitation for children and youth
A.8. Rehabilitation for people with old age
A.9. Rehabilitation for rare (orphan) diseases
A.10. Rehabilitation addressing to specific functioning issues
A.11. Sports rehabilitation
A.12. Miscellaneous

B. Biosciences in PRM
B.1. Mechanisms of tissue injury and development of organ dysfunction
B.2. Cell and tissue adaptation and mal-adaptation
B.3. Autonomous regulation
B.4. Biological mechanism of interventions
B.5. Miscellaneous

C. Biomedical Rehabilitation Sciences and Engineering
C.1. Physical and Rehabilitation Medicine (PRM) diagnostics as related to organ systems and body functions
C.2. PRM interventions research
C.3. Comprehensive rehabilitation programmes research
C.4. Miscellaneous

D. Integrative Rehabilitation Sciences
D.1. Rehabilitation systems and services research
D.2. Comprehensive rehabilitation intervention research
D.3. Social integration programmes and rehabilitation for specific socio-economic needs
D.4. Education and training in rehabilitation
D.5. Rehabilitation management and administration
D.6. Miscellaneous

E. Human Functioning Sciences
E.1. Theories and models of functioning
E.2. Classification of functioning
E.3. Measurement of functioning
E.4. Functioning epidemiology
E.5. Functioning impact assessment
E.6. Ethical issues and human rights
E.7. Cultural aspects of disability and rehabilitation
E.8. Miscellaneous

CONTRIBUTION OF PHYSICAL AND REHABILITATION MEDICINE RESEARCH TO HEALTHCARE SYSTEM LEVELS

Improved understanding of the contribution of the areas of the scientific field of PRM to the healthcare system levels will demonstrate synergistic value for

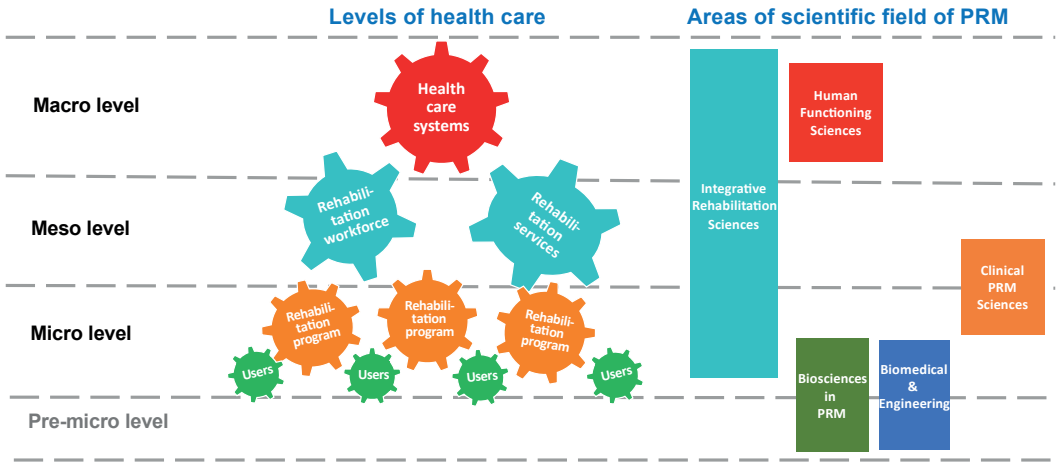

Fig. 3. Linking of levels of healthcare in rehabilitation with areas of the scientific field of Physical and Rehabilitation Medicine (PRM).

comprehensively improving rehabilitation as a health strategy. However, it is clear that there are interrelations and overlap between the contribution of these areas (Fig. 3).

Biosciences and biomedical and engineering in rehabilitation can be linked with the healthcare system and their contribution categorized into pre-micro- and micro-levels of. The term "pre-micro-level" is used for basic sciences that are not directly covered at the level of the healthcare system. However, this category must not be neglected, as it is an important, relevant and integral part of the scientific research supporting the overall healthcare system. The pre-micro-level covers other scientific fields in the preclinical setting, e.g. study of the pathomechanisms of diseases at the cellular level or in animal models. Biosciences and biomedical and engineering in rehabilitation are based on research in cells, animals and humans. Examples of research in these fields include: microRNAs that mediate the anticancer effect of physical activity (22); the role of immune cells in multiple sclerosis (23); and regulation of pain by non-neuronal cells and inflammation (24). Research in animal models can be designed to study the pathomechanism of diseases, interventions, and to observe functioning, such as gait analysis in animal stroke models (25). An example of biomedical and engineering in rehabilitation in the animal model is research into exoskeletons for neurological disorders (26). Examples of bioscience research in humans (micro-level) include study of the pathomechanism of disease in patients with fibromyalgia syndrome (27, 28) and alterations at the molecular level to develop more effective treatments (29) (see Table II).

Clinical PRM sciences can be linked with the healthcare system and their contribution categorized into both micro- and meso-level. In addition to supporting best practice treatment for the patients (micro-level), researches also include education and training for PRM professionals (meso level) (8). Examples of clinical PRM research at the micro-level are studies comparing rehabilitation treatments in chronic low back pain (30) and breast cancer survivors (31). An example of clinical PRM science at the meso-level is teamwork communication for rehabilitation professionals (32) (see Table II).

Integrative rehabilitation sciences can be linked with the healthcare system and their contibution categorized into micro- to macro-level. At the micro-level, an example is the economic evaluation of vocational rehabilitation for patients with chronic musculoskeletal pain (33). At the meso-level, an example is the description of rehabilitation service organization (8, 9) and research related to return to work (34) (see Table II). Macro-level research includes the development of rehabilitation situation assessment tools and WHO support packages for the country- or province-level (11, 13), implementation of these tools to develop national health action plans for disability and rehabilitation (14, 16), analysis and implementation of WHO documents (35), and implementation of clinical quality management for rehabilitation in Malaysia (12) (see Table II).

Human functioning sciences can be linked with the healthcare system and their contribution placed in the macro-level of healthcare system. Examples include the development of ICF Core Sets, validity of ICF Core Sets for specific health conditions (36), and development of functioning properties to be used in the International Classification of Disease – 11 (ICD-11) (37). The use of ICF at individual level is categorized at the micro-level, which is under the area of clinical PRM sciences (see Table II).

Table II. Examples of research in different areas of the scientific field of Physical and Rehabilitation Medicine (PRM), divided into pre-micro-, micro-, meso-, and macro-levels of the healthcare system

Macro	*Human Functioning Sciences*	• International Classification of Functioning, Disability and Health (ICF) (19) • The IASP classification of chronic pain for ICD-11: functioning properties of chronic pain (37)	• Development of ICF • Development of functioning properties for chronic pain to be used in ICD-11
	Integrative Sciences	Principles of Assessment of Rehabilitation Services in Health System: Learning from Experiences (11)	Developing tool to assess rehabilitation service at health system level in country/province
		• Situation analysis of rehabilitation service to support the national disability and rehabilitation plan in the Democratic People´s Republic of Korea (16) • Responding to the World Health Organization (WHO) Global Disability Action Plan (GDAP) in Egypt: A Technical Consultancy to develop a National Disability, Health and Rehabilitation Plan (14)	Development of an action plan at country level
		Analysis and implementation of a World Health Organization health report: methodological concepts and strategies (35)	Analysis and implementation of WHO documents
		Implementation of Clinical Quality Management for Rehabilitation in Malaysia (12)	ICF based for clinical quality management for rehabilitation in Malaysia
Meso	*Integrative Sciences*	ISPRM Discussion Paper: Proposing Dimensions for an International Classification System for Service Organization in Health-Related Rehabilitation (8)	Describing rehabilitation service organization
		Adaptation of a Guide to Equip Employers to Manage the Gradual Return to Work of Individuals with a Musculoskeletal Disorder (34)	Return to work by adaptation (participation)
	Clinical PRM Sciences	Inter-professional communication and interaction in the neurological rehabilitation team: a literature review. (32)	Teamwork in rehabilitation
Micro	*Clinical PRM Sciences*	Comparison of the effects of stability exercise and balance exercise on muscle activity in female patients with chronic low back pain (30)	Comparing 2 different treatments for patient
		Influence of a Multimodal and Multimodal-Aerobic Therapy Concept on Health-Related Quality of Life in Breast Cancer Survivors (31)	
		Performance of brief ICF-sleep disorders and obesity core set in obstructive sleep apnoea patients (38)	Use of the ICF
	Integrative Rehabilitation sciences	Vocational rehabilitation for patients with chronic musculoskeletal pain with or without a work module: an economic evaluation (33)	Economic evaluation of vocational rehabilitation for patients with chronic musculoskeletal pain
	Biomedical and Engineering in Rehabilitation	• Stride management assist exoskeleton vs functional gait training in stroke: a randomized trial (39) • Real-time evaluation of the signal processing of sEMG used in limb exoskeleton rehabilitation system (40)	Robotic to improve performance
	Biosciences in Rehabilitation	• Serum level of brain-derived neurotrophic factor in fibromyalgia syndrome correlates with depression but not anxiety (27) • Polymorphisms of brain-derived neurotrophic factor genes are associated with anxiety and body mass index in fibromyalgia syndrome patients (28)	Pathomechanism of disease in patients
		Neuromuscular electrical stimulation training induces atypical adaptations of the human skeletal muscle phenotype: a functional and proteomic analysis (29)	Effect of treatment and alteration at molecular level
		Functional capacity change impacts the quality of life of hospitalized patients undergoing hematopoietic stem cell transplantation (41)	Stem cell transplantation to improve functional capacity (human experiment)
		Anticancer effect of physical activity is mediated by modulation of extracellular microRNA in blood (22)	The role of miRNA and neurodegenerative disorder (human experiment)
Pre-Micro	*Biomedical Rehabilitation Sciences and Engineering*	• Rehabilitative soft exoskeleton for rodents (26)	Exoskeleton for neurological disorder in animal model
	Biosciences in Rehabilitation	• Inhibition of miR-497 improves functional outcome after ischemic stroke by enhancing neuronal autophagy in young and aged rats (42). • A novel model for studying voltage-gated ion channel gene expression during reversible ischemic stroke (25)	Animal experiment and pathomechanism of diseases
		Pain regulation by non-neuronal cells and inflammation (24)	Non-neuronal cells and pain

ICF: International Classification of Functioning, Disability and Health; IASP: International Association for the Study of Pain; ICD: International Classification of Diseases; WHO: World Health Organization; GDAP: Global Disability Action Plan; ISPRM: International Society of Physical and Rehabilitation Medicine; miRNA: Micro ribonucleic acid.

CONCLUSION

Scientific evidence is an important factor in many fields, including health. In rehabilitation, scientific research should be synergized to strengthen rehabilitation at all levels of the healthcare system. Scientific areas of PRM can provide valuable scientific evidence, support best practice, and strengthen rehabilitation at all levels of the healthcare system. This can be seen as a model for relevant stakeholders to prioritize research in the fields of PRM in order to reach the goal of improving rehabilitation at all levels of healthcare.

ACKNOWLEDGEMENT

This study was supported by the Department of Rehabilitation Medicine, Hannover Medical School, Hannover, Germany.

The authors have no conflicts of interest to declare.

REFERENCES

1. World Health Organization (WHO). Global disability action plan. Geneva: WHO; 2014.
2. World Health Organization (WHO). Recommendations: rehabilitation in health systems 2017; Geneva: WHO; 2017.
3. Stucki G, Grimby G. Organizing human functioning and rehabilitation research into distinct scientific fields. Part

I: Developing a comprehensive structure from the cell to society. J Rehabil Med 2007; 39: 293–298.
4. Gutenbrunner C, Nugraha B. Physical and rehabilitation medicine: responding to health needs from individual care to service provision. Eur J Phys Rehabil Med. 2017; 53: 1–6.
5. World Health Organization (WHO), The World Bank. World report on disability. Geneva: WHO; 2011.
6. Meyer T, Gutenbrunner C, Bickenbach J, Cieza A, Melvin J, Stucki G. Towards a conceptual description of rehabilitation as a health strategy. J Rehabil Med 2011; 43: 765–769.
7. European Physical and Rehabilitation Medicine Bodies Alliance. White book on physical and rehabilitation medicine in Europe. Introductions, executive summary, and methodology. Eur J Phys Rehabil Med 2018; 54: 125–155.
8. Gutenbrunner C, Bickenbach J, Kiekens C, Meyer T, Skempes D, Nugraha B, et al. ISPRM discussion paper: proposing dimensions for an International Classification System for Service Organization in Health-related Rehabilitation. J Rehabil Med 2015; 47: 809–815.
9. Gutenbrunner C, Nugraha B, Gimigliano F, Meyer T, Kiekens C. International classification of service organization in rehabilitation: an updated set of categories (ICSO-R 2.0). J Rehabil Med 2020; 52: jrm00004.
10. Gutenbrunner C, Bickenbach J, Melvin J, Lains J, Nugraha B. Strengthening health-related rehabilitation services at national levels. J Rehabil Med 2018; 50: 317–325.
11. Gutenbrunner C, Nugraha B. Principles of assessment of rehabilitation services in health systems: learning from experiences. J Rehabil Med 2018; 50: 326–332.
12. Engkasan JP, Stucki G, Ali S, Yusof YM, Hussain H, Latif LA. Implementation of clinical quality management for rehabilitation in Malaysia. J Rehabil Med 2018; 50: 346–357.
13. World Health Organization (WHO). WHO rehabilitation support package. 2018 [cited 2019 Jan 23]; Available from: https://www.who.int/rehabilitation/en/.
14. Gutenbrunner C, Nugraha B. Responding to the World Health Organization Global Disability Action Plan in Egypt: a technical consultancy to develop a national disability, health and rehabilitation plan. J Rehabil Med 2018; 50: 333–337.
15. Gutenbrunner C, Tederko P, Grabljevec K, Nugraha B. Responding to the World Health Organization Global Disability Action Plan in Ukraine: developing a national disability, health and rehabilitation plan. J Rehabil Med 2018; 50: 338–341.
16. Nugraha B, Gutenbrunner C. Situation analysis of rehabilitation service to support the national disability and rehabilitation plan in the Democratic People s Republic of Korea. J Rehabil Med 2018; 50: 342–345.
17. Gutenbrunner C, Bickenbach J, Melvin J, Lains J, Nugraha B. Strengthening health-related rehabilitation services at national levels. J Rehabil Med 2018; 50: 333–337.
18. Stucki G, Bickenbach J, Gutenbrunner C, Melvin J. Rehabilitation: the health strategy of the 21st century. J Rehabil Med 2018; 50: 309–316.
19. World Health Organization (WHO). International classification of functioning, disability and health: ICF. Geneva: WHO; 2001.
20. Gutenbrunner C, Ward AB, Li LS, Li J, Guzman M, Fialka-Moser V, et al. Spectrum of topics for World Congresses and other activities of the International Society for Physical and Rehabilitation Medicine (ISPRM): a first proposal. J Rehabil Med 2013; 45: 1–5.
21. Nugraha B, Paternostro-Sluga T, Schuhfried O, Stucki G, Franchignoni F, Abdul Latif L, et al. Evaluation of the topic lists used in two world Congresses (2015 and 2016) in Physical and Rehabilitation Medicine. J Rehabil Med 2017; 49: 469–474.
22. Alessandra P, Ming Y, Pradeep CR, Barbara M, Cinzia D, Barbara B, et al. Anticancer effect of physical activity is mediated by modulation of extracellular microRNA in blood. Oncotarget 2020; 11: 2106–2119.
23. Staun-Ram E, Miller A. Effector and regulatory B cells in multiple sclerosis. Clin Immunol 2017; 184: 11–25.
24. Ji RR, Chamessian A, Zhang YQ. Pain regulation by non-neuronal cells and inflammation. Science 2016; 354: 572–577.
25. Tai YS, Yang SC, Hsieh YC, Huang YB, Wu PC, Tsai MJ, et al. A novel model for studying voltage-gated ion channel gene expression during reversible ischemic stroke. Int J Med Sci 2019; 16: 60–67.
26. Florez JM, Shah M, Moraud EM, Wurth S, Baud L, Von Zitzewitz J, et al. Rehabilitative soft exoskeleton for rodents. IEEE transactions on neural systems and rehabilitation engineering: a publication of the IEEE Engineering in Medicine and Biology Society 2017; 25: 107–118.
27. Nugraha B, Korallus C, Gutenbrunner C. Serum level of brain-derived neurotrophic factor in fibromyalgia syndrome correlates with depression but not anxiety. Neurochem Int 2013; 62: 281–286.
28. Nugraha B, Anwar SL, Gutenbrunner C, Korallus C. Polymorphisms of brain-derived neurotrophic factor genes are associated with anxiety and body mass index in fibromyalgia syndrome patients. BMC Res Notes 2020; 13: 402.
29. Gondin J, Brocca L, Bellinzona E, D'Antona G, Maffiuletti NA, Miotti D, et al. Neuromuscular electrical stimulation training induces atypical adaptations of the human skeletal muscle phenotype: a functional and proteomic analysis. J Appl Physiol 2011; 110: 433–450.
30. Kim DH, Kim TH. Comparison of the effects of stability exercise and balance exercise on muscle activity in female patients with chronic low back pain. J Exerc Rehabil 2018; 14: 1053–1058.
31. Poier D, Bussing A, Rodrigues Recchia D, Beerenbrock Y, Reif M, Nikolaou A, et al. Influence of a multimodal and multimodal-aerobic therapy concept on health-related quality of life in breast cancer survivors. Integr Cancer Ther 2019; 18: 1534735418820447.
32. Franz S, Muser J, Thielhorn U, Wallesch CW, Behrens J. Inter-professional communication and interaction in the neurological rehabilitation team: a literature review. Disabil Rehabil 2020; 42: 1607–1615.
33. Reneman MF, Beemster TT, Welling SJ, Mierau JO, Dijk HH. Vocational rehabilitation for patients with chronic musculoskeletal pain with or without a work module: an economic evaluation. J Occup Rehabil 2020; doi: 10.1007/s10926-020-09921-y [Epub ahead of print].
34. Bouffard J, Durand MJ, Coutu MF. Adaptation of a guide to equip employers to manage the gradual return to work of individuals with a musculoskeletal disorder. J Occup Rehabil 2019; 29: 625–635.
35. von Groote PM, Giustini A, Bickenbach JE. Analysis and implementation of a World Health Organization health report methodological concepts and strategies. Am J Phys Med Rehabil 2014; 93: S12–S26.
36. Wildeboer AT, Stallinga HA, Roodbol PF. Validation of the International Classification of Functioning, Disability and Health (ICF) Core Set for diabetes mellitus from nurses' perspective using the Delphi method. Disabil Rehabil 2020: 1–9. [Epub ahead of print].
37. Nugraha B, Gutenbrunner C, Barke A, Karst M, Schiller J, Schafer P, et al. The IASP classification of chronic pain for ICD-11: functioning properties of chronic pain. Pain 2019; 160: 88–94.
38. Xie L, Wu Q, Hu W, Li W, Xiang G, Hao S, et al. Performance of brief ICF-sleep disorders and obesity core set in obstructive sleep apnea patients. Respir Res 2020; 21: 156.
39. Jayaraman A, O'Brien MK, Madhavan S, Mummidisetty CK, Roth HR, Hohl K, et al. Stride management assist exoskeleton vs functional gait training in stroke: a randomized trial. Neurology 2019; 92: e263–e273.
40. Gao B, Wei C, Ma H, Yang S, Ma X, Zhang S. Real-time evaluation of the signal processing of sEMG used in limb exoskeleton rehabilitation system. Appl Bionics Biomech 2018; 2018: 1391032.
41. de Almeida LB, Mira PAC, Fioritto AP, Malaguti C, Neto AEH, Trevizan PF, et al. Functional capacity change impacts the quality of life of hospitalized patients undergoing hematopoietic stem cell transplantation. Am J Phys Med Rehabil 2019; 98: 450–455.
42. Chen X, Lin S, Gu L, Zhu X, Zhang Y, Zhang H, et al. Inhibition of miR-497 improves functional outcome after ischemic stroke by enhancing neuronal autophagy in young and aged rats. Neurochem Int 2019; 127: 64–172.