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Preface

This volume, Oxford Textbook of Clinical Neurorehabilitation, mainly reflects insights from knowledge gained over the last 25 years. It covers the most relevant aspects of neurorehabilitation approaches as currently applied, most of which are dependent, to a large degree, upon advances made through basic, clinical, therapeutic, social, and technological research during recent decades. We asked the authors-all of whom are acknowledged experts in a specific field of neurorehabilitation-to present their chapters with the current state of the art in their area and, as far as possible, the scientific basis on which contemporary treatment approaches are based. The authors were also asked to make their chapters attractive and accessible for both specialists and non-specialists involved in the neurorehabilitation of patients by including videos, illustrations, and tables to provide a summary of particular aspects of their subject. Where appropriate, different perspectives on a given field are also provided. This volume should serve as a current overview covering all aspects of neurorehabilitation for medical doctors, scientists and therapists working in this diverse and advancing field.

Impressive progress has been made in the field of neurorehabilitation over recent decades. This period of change dawned with an almost exclusively experience-based neurorehabilitation approach, inaugurated by a number of schools and usually practiced in separation from other medical disciplines. Over time, in most subspecialities, evidence-based neurorehabilitation has been gradually established. This move towards a more scientific and integrated paradigm is illustrated by smoother transitions from acute care: for instance, stroke patients into early rehabilitation requiring close multidisciplinary interactions characterized by close cooperation between clinical staff and researchers. This early phase of rehabilitation is followed by longer-term functional training approaches and social integration programmes, which are today being successfully applied for patients with stroke, brain injury, and spinal cord injury (SCI). Such modern rehabilitation approaches have strong theoretical underpinnings, for instance on evidence gained from animal experiments investigating the exploitation potential of neuroplasticity or from well-conducted patient studies concerning the effect of longer training times on the recovery of sensorimotor function during rehabilitation in patient with various forms of central (CNS) and peripheral nervous system damage. However, despite all this recent progress, we must acknowledge the evident limitations of our treatment approaches. After severe CNS damage neurological deficits remain, and our ongoing aim can only be to achieve more optimal outcomes for individual patients.

Repetitive training of lost functional movements has become established for the recovery of sensorimotor function. This has been associated with an increase in the use and impact of technology in contemporary neurorehabilitation programmes, using assistive devices, feedback information, and virtual reality training conditions. This technology allows standardized training sessions and objective measurement of the trajectory of movement recovery and can motivate the patient through feedback over the course of rehabilitation. Today, the significance of this technology is occasionally considered to be overestimated and its further development is critically discussed. Further progress with technology must be driven by recognition of the physiological requirements for its beneficial application. Nevertheless, there are few doubts that technology will continue to have an increasing impact in neurorehabilitation.

Despite all these promising developments, in several respects there are still hurdles to overcome if we are to achieve optimal neurorehabilitation strategies. Although concepts such as neuroplasticity are well attested in animal experiments, a major problem still concerns the successful translation of basic research into clinical applications. Several causes may perpetuate this problem. Despite promising techniques for inducing neural regeneration in animal models, applying therapies based on these concepts in human patients with SCI has not yet shown convincing results. This failure may be due to the lack of an adequate animal model and a solution will require close cooperation between researchers and clinicians involved in the care of patients with CNS damage.

We are also still at the beginning of building a true understanding of the factors which underlie and influence training effects. For example, which proprioceptive input is required to achieve meaningful limb muscle activation, in turn leading to training effects resulting in improved sensorimotor functional outcomes? How can a treatment programme be optimally adapted to individual abilities and requirements, for example, with respect to movement velocity and complexity? To what extent must training of particular factors, such as equilibrium control during stepping, be challenging?

We must also be aware of the increasing population of elderly people requiring neurorehabilitation. This is having and will continue to have profound medical, therapeutic and social consequences. This situation is frequently neglected and solutions must be identified and developed in the near future. One such solution might be improved transition from an initial, short, focused neurorehabilitation period in specialized centres, prior to early integration into community- or home-based rehabilitation with community-based nursing care and an environment adapted to the individual's needs and access to neurorehabilitation specialists.

Observations indicate that neuroplasticity can still be successfully exploited in elderly patients and lead to a degree of neurological recovery similar to that possible in young patients, although translation in functional gains is usually poor. Elderly people thus require special training approaches focused on a few important daily life activities, something often more successfully achieved in a familiar setting (i.e. at home or in the community) rather than in a specialized centre where elderly people may have difficulty adapting to an unfamiliar setting.

In the future, prediction of outcome will be further improved and will determine the focus of training approaches to be applied. It might not only allow the optimization of sensorimotor functional rehabilitation but also prevent complications of autonomic dysfunction and the development of pain syndromes. Such early outcome predictions, particularly for sensorimotor functions, are available today, usually using a combination of electrophysiological and imaging assessments in conjunction with clinical examination.

If rehabilitation medicine is to continue its recent progression, close cooperation between basic and clinical research, therapists, and engineers is required to develop and promote useful assessments for an early refined prediction of outcome (sensorimotor and autonomic function and pain syndromes) with the aim of establishing standardized, but individually adapted, treatment programmes.

Volker Dietz
Nick Ward

Contents

SECTION 4
Clinical concepts

SECTION 5
Technical concepts

Abbreviations

5-HT	5-hydroxytryptamine
AAC	alternative augmentative communication
ABG	arterial blood gas
Ach	acetylcholine
AD	autonomic dysreflexia
AD	Alzheimer's disease
ADH	antidiuretic hormone
ADHD	attention deficit hyperactivity disorders
ADL	activities of daily living
AFO	ankle–foot orthoses
AIS	American Spinal Injury Association Impairment Scale
AMA	antimitochondrial antibodies
AMPS	Assessment of Motor and Process Skills
ANA	antinuclear antibodies
ANS	autonomic nervous system
APBT	active–passive bilateral training
ARAT	Action Research Arm Test
ASD	autistic spectrum disorder
ASIA	American Spinal Injury Association
ATC	assistive technology for cognition
AUC	area under the curve
BAT	bilateral arm training
BATRAC	Bilateral arm training with rhythmic auditory cueing
BB	Box and Blocks Test
BDNF	brain-derived neurotrophic factor
BI	Barthel Index
BMSC	bone marrow stromal cells
BNAVE	Balance Near Automatic Virtual Environment
BOLD	blood oxygen level-dependent
BP	blood pressure
BrdU	bromodeoxyuridine
BWS	body weight support
BWSTT	body weight-supported treadmill training
CAHAI	Chedoke Arm and Hand Activity Inventory
CAT	computer-assisted therapy
CBF	cerebral blood flow
CBS	Catherine Bergego Scale
CBT	cognitive-behavioural therapy
CCS	central cord syndrome
CF	cystic fibrosis
CFS	chronic fatigue syndrome
CHEP	contact heat evoked potential
CI	confidence interval
CIDP	chronic inflammatory demyelinating polyradiculoneuropathy
CIMT	constrained induced movement therapy
CISC	clean intermittent self-catheterization
CM	centre of mass
CMA	cingulate motor area
CMAd	dorsal cingulate motor area
CMT	Charcot–Marie–Tooth
CMV	cytomegalovirus
CNP	central neuropathic pain
CNS	central nervous system
CONSORT	CONsolidated Standards of Reporting Trials Statement
CoP	centre of pressure
CPG	central pattern generator
CRP	C-reactive protein
C-SCI	cervical spinal cord injury
CST	corticospinal tract system
CST	corticospinal tract
CT	combined training
CVS	cardiovascular system
CWRU	Case Western Reserve University
CXR	chest X-ray
DA	dopamine
DALY	disability adjusted life year
DCML	dorsal column medial lemniscus
DDAVP	desmopressin acetate
DFNS	German Network on Neuropathic Pain
DG	dentate gyrus
DLB	dementia with Lewy bodies
DMB	Data Monitoring Board
DO	detrusor overactivity
DOF	degrees of freedom
DSD	detrusor-sphincter-dyssynergia
DTI	diffusion tensor imaging
DWI	Diffusion-weighted imaging
EADL	electronic aid for daily living
EAE	experimental autoimmune encephalomyelitis
EBV	Epstein–Barr virus
EEG	electroencephalography
eEmc	electrical enabling motor control
EFNS	European Federation of Neurological Societies Task Force

EFNS	European Federation of Neurological Societies
EMA	European Medicines Agency
emEmc	electromagnetic stimulation enabling motor control
EMG	electromyography
ENA	extractable nuclear antigens
ES	electrical stimulation
ESC	embryonic stem cells
ESD	early supported discharge
ESR	erythrocyte sedimentation rate
ET	endurance training
EUS	external urethral sphincter
EXCITE	Extremity Constraint Induced Therapy Evaluation
FA	fractional anisotropy
FBC	full blood count
FDA	Food and Drug Administration
FEES	fibreoptic endoscopic evaluation of swallowing
fEmc	Pharmacological enabling motor control
FES	functional electrical stimulation
FIM	Functional Independence Measure
FINE	flat interface nerve electrode
FLAME	Fluoxetine for Motor Recovery after Acute Ischaemic Stroke
FM score	Fugl-Meyer Motor Score
FMA	Fugl-Meyer Arm scale
FMS	Fugl-Meyer Scale
FRA	flexor reflex afferent
FST	functional strength training
GABA	gamma-aminobutyric acid
GABAAR	GABA type A receptor
GABABR	GABA type B receptor
GAPS	Glasgow Augmented Physiotherapy after Stroke
GBA	glucocerebrosidase
GCS	Glasgow Coma Scale
GET	graded exercise therapy
GI	gastrointestinal
GMC	General Medical Council
GMT	goal-management training
GNP	grasping neuroprosthesis
GRADE	Grading of Recommendations Assessment, Development and Evaluation
GRASP	graded repetitive arm supplementary programme
GRASPP	Graded Redefined Assessment of Strength, Sensibility and Prehension
GRF	ground reaction force
GSR	galvanic skin response
HAS	hybrid assistive system
HD	Huntington's disease
HIV	human immunodeficiency virus
HOS	hybrid orthotic system
HPA	hypothalamic-pituitary-adrenal
HR	heart rate
HRG	healthcare resource group
IASP	International Association for the Study of Pain
ICC	intraclass correlation coefficients
ICD 10	International Classification of Diseases 10th edition
ICF	International Classification of Functioning, Disability, and Health
ICF	International Classification of Functioning
ICF model	International Classification of Functioning, Disability and Health Model
ICIDH	International Classification of Impairments, Disabilities and Handicaps
IFN-α	interferon-α
IFN-β	interferon-β
IMMPACT	Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials
iPSC	inducible pluripotent stem cells
IRB	
ISCIBPD	International Spinal Cord Injury Basic Pain Dataset
ISCIP	International Spinal Cord Injury Pain Classification
ISNCSCI	International Standards for Neurological Classification of Spinal Cord Injury
ISRCTN	International Standard Randomized Control Trial Number
ITB	intrathecal baclofen
JTT	Jebsen–Taylor Hand Function Test
L-DOPS	l-threo-3,4-dihydroxyphenylserine
LFT	liver function test
LMR	locomotor mesencephalic region
L-NAME	nitro-l-arginine methyl ester
LOS	length of stay
LTD	long-term depression
LTNC	long-term neurological condition
LTP	long-term potentiation
LTP	long-term potentiation
LUT	lower urinary tract
M1	primary motor cortex
MAL	Motor Activity Log
MCAO	middle cerebral artery occlusion
MCI	mild cognitive impairment
MCID	minimal clinically important difference
MEG	magnetoencephalography
MEP	motor-evoked potential
MeSH	Medical Subject Headings
MHADIE	Measuring Health and Disability in Europe
MI	Motricity Index
MIBG	metaiodobenzylguanidine
MIME	mirror image movement enabling
MPI	Multidimensional Pain Inventory
MRI	magnetic resonance imaging
MS	multiple sclerosis
MSA	multiple system atrophy
MSC	mesenchymal stem cell
MSU	mid-stream urine
mTBI	minor traumatic brain injury
MUST	Malnutrition Universal Screening Tool
MVC	maximal voluntary contraction
NANC	non-adrenergic non-cholinergic
NBD	neurogenic bowel dysfunction
NCS	nerve conduction studies
NDO	neurogenic detrusor overactivity
NE	norepinephrine
NG	nasogastric
NGF	nerve growth factor

NIBS	non-invasive brain stimulation
NICE	National Institute of Health and Care Excellence
NIH	National Institutes of Health
NIHSS	National Institutes of Health Stroke Scale
NLI	neurological level injury
NLUTD	neurogenic lower urinary tract dysfunction
NMDAR	NMDA receptor
NMES	neuromuscular electrical stimulation
NMDA	*N*-methyl-D-aspartate
NNT	number needed to treat
NP	neuroprosthesis
NPC	neural precursor cells
NPS	Neuropathic Pain Scale
NPSI	Neuropathic Pain Symptom Inventory
NRS	Numerical rating scale
NSAID	non-steroidal anti-inflammatory drug
NSC	Neural stem cells
NSPC	neural stem/progenitor cells
OA	osteoarthritis
OB	olfactory bulb
OEC	olfactory ensheathing cells
OH	orthostatic hypotension
OM	opposing muscle
OT	other training
PAF	pure (primary) autonomic failure
PAG	periaqueductal grey
PAS	paired associative stimulation
pcEmc	transcutaneous electrical stimulation
PCS	post-concussion syndrome
PD	Parkinson's disease
PEFR	peak expiratory flow rate
PEG	percutaneous endoscopic gastrostomy
PET	positron emission tomography
PLIC	posterior limb of the internal capsule
PLMD	periodic limb movement disorder
PLORAS	predicting language outcome and recovery after stroke
PMC	pontine micturition centre
PMd	dorsolateral premotor cortex
PMv	ventrolateral premotor cortex
PNF	proprioceptive neuromuscular facilitation
PNS	peripheral nervous system
POTS	postural orthostatic tachycardia syndrome
pQCT	peripheral quantitative computed tomography
PREP	Predicting REcovery Potential
PTEN	phosphatase and tensin homologue
PTSD	post-traumatic stress disorders
PVS	permanent vegetative state
PWD	persons with disabilities
QALY	quality-adjusted life year
QDIRT	quantitative direct and indirect test of sudomotor function
QSART	quantitative sudomotor axon reflex test
QST	quantitative sensory testing
RCT	randomized controlled trial
RLS	restless leg syndrome
RMS	rostral migratory stream
ROM	range of motion
RT	resistance training
rTMS	repetitive transcranial magnetic stimulation
SARS	sacral anterior root stimulator
SC	Schwann cells
SCI	spinal cord injury
SCIM	Spinal Cord Independence Measure
SGZ	subgranular zone
SIS	Stroke Impact Scale
SLE	systemic lupus erythematosus
SMA	supplementary motor area
SNRI	serotonin-noradrenaline reuptake inhibitors
SPECT	single-photon emission computed tomography
SR	spinal reflex
SREBR	Stroke Rehabilitation Evidence-Based Review
SSEP	somatosensory evoked potential
SSR	sympathetic skin response
SSRI	Selective serotonin reuptake inhibitor
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
STT	spinothalamic tract
SVZ	subventricular zone
TBI	traumatic brain injury
TBS	theta burst stimulation
TCA	tricyclic antidepressant
TcMEP	transcranial motor evoked potential
TCT	trunk control test
TDCS	transcranial direct current stimulation
tDCS	transcranial direct current stimulation
TENS	transcutaneous electrical nerve stimulation
TES	therapeutic electrical stimulation
TFT	thyroid function test
TIA	transient ischaemic attack
TLE	temporal lobe epilepsy
TM	target muscle
TMS	transcranial magnetic stimulation
tRNS	transcranial random noise stimulation
tsDCS	transcutaneous spinal direct current stimulation
TST	thermoregulatory sweat test
TTZ	training target zone
U&Es	urea and electrolytes
UDP	use-dependent plasticity
UTI	urinary tract infection
VA	Veterans Affairs
VECTORS	Very Early Constraint-Induced Movement during Stroke Rehabilitation
VI	visual illusion
VM	ventral mesencephalic
VR	virtual reality
VRMT	VR-aided memory training
WHO	World Health Organization
WISC II	Walking Index for Spinal Cord Injury II (WISCI II)
WISCI	Walking Index for Spinal Cord Injury
WMFT	Wolf Motor Function Test
WNP	walking neuroprosthesis

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SECTION 1

General aspects of neurorehabilitation

CHAPTER 1

The International Classification of Functioning, Disability, and Health

Diane Playford

The International Classification of Functioning, Disability, and Health (ICF) provides a framework for the description of health and health-related states and offers a biopsychosocial model of disability. It lists body functions and structure, and activity and participation. The relationship between impairment, activity, and participation is not linear, and can be further moderated by contextual factors, including personal and environmental factors. Each of these components is denoted by a prefix, followed by a numeric code, and then a qualifier, which also has a numeric value. This approach allows clear description of each domain, the extent of any impairment, and the level of performance and capacity at the activity and participation level. There are a wide range of potential applications of the ICF. It has been adopted most widely within rehabilitation services to describe individual functioning, but can also be used at a service and national policy level to describe, monitor, and evaluate different activities. This chapter aims to outline the use of the ICF, consider its strengths, and highlight its function in a range of settings.

The ICF was introduced by the World Health Organization (WHO) in 1999 as a response to the conceptual and practical difficulties posed by its predecessor, the International Classification of Impairment, Disability and Handicap (ICIDH) [1]. For many years there was a tension between medical and social models of disability. In the medical model disability was seen as a problem of the individual's body, whereas the social model identified disability as a consequence of the external environment and societal attitudes [2]. These two views polarize the debate. While it is clearly not acceptable for an individual to be denied their role in society through barriers created by the social, political and physical environment, it is also appropriate for clinicians, if requested, to treat pain, spasticity, weakness and other symptoms.

It is clear that such polarized views were never the only views on this debate. Gzil and colleagues [3] chart clearly the evolution of thinking around disability. However, over the past ten years thinking has shifted as is exemplified by the adoption of the biopsychosocial model of disability described in the WHO ICF. When this was first published adoption was slow, but it is now accepted as a practical model of disability. This chapter will outline the ICF, consider how widely it has been adopted, and identify some of the remaining issues in its widespread adoption and use.

The ICF provides a framework for the description of health and health-related states. It lists body functions and structure, and activity and participation [1]. Functioning refers to all body functions, activities, and participation, while disability is used for impairments, activity limitations, and participation restrictions. The relationship between impairment, activity, and participation is not linear, and can be further moderated by contextual factors, including personal and environmental factors. Body structures and functions, activities, participations, and environmental factors are coded, whereas personal factors are not. For example, the loss of a little finger is an impairment of body structure; in most people this will result in little change in activity or participation, but for an international concert violinist the participation restriction will be considerable and will impact on their ability to maintain paid work. However, whether they are able to accept this participation restriction and go on to find other paid work, say as a cab driver, will depend on personal factors including values and beliefs about paid work, and environmental factors such as their families willingness to support them financially.

The ICF can be drawn out schematically as shown in Figure 1.1.

- **Body functions** are physiological functions of body systems (including psychological functions). Examples of body functions include cognitive and emotional functioning; vision; hearing; and cardiovascular, respiratory, digestive, reproductive, and musculoskeletal functions.
- **Body structures** are anatomical parts of the body such as organs, limbs, and their components. Examples include the oesophagus, stomach, intestine, pancreas, and liver or the brain, spinal cord, and meninges.
- **Impairments** are problems in body function or structure, such as a significant deviation or loss. Examples would include respiratory failure or limb loss.
- **Activity** is the execution of a task or action by an individual, for example, lifting and carrying objects.