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Rehabilitation impact indices and their independent predictors: a systematic review

Gerald Choon-Huat Koh,[1] Cynthia Huijun Chen,[1] Robert Petrella,[2,3] Amardeep Thind[2]

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GCK and CHC contributed equally to this work.

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[1]Saw Swee Hock School of Public Health, National University of Singapore, National University Health System, Singapore, Singapore
[2]Department of Family Medicine, Schulich School of Medicine & Dentistry, University of Western Ontario, London, Ontario, Canada
[3]Lawson Health Research Institute, London, Ontario, Canada

Correspondence to
Dr Gerald C Koh;
Gerald_Koh@nuhs.edu.sg

ABSTRACT

Objectives: To (1) identify all available rehabilitation impact indices (RIIs) based on their mathematical formula, (2) assess the evidence for independent predictors of each RII and (3) propose a nomenclature system to harmonise the names of RIIs.
Design: Systematic review.
Data sources: PubMed and references in primary articles.
Study selection: First, we identified all available RII through preliminary literature review. Then, various names of the same formula were used to identify studies, limited to articles in English and up to 31 December 2011, including case–control and cohort studies, and controlled interventional trials where RIIs were outcome variable and matching or multivariate analysis was performed.
Results: The five RIIs identified were (1) absolute functional gain (AFG)/absolute efficacy/total gain, (2) rehabilitation effectiveness (REs)/Montebello Rehabilitation Factor Score (MRFS)/relative functional gain (RFG), (3) rehabilitation efficiency (REy)/length of stay-efficiency (LOS-EFF)/efficiency, (4) relative functional efficiency (RFE)/MRFS efficiency and (5) revised MRFS (MRFS-R). REy/LOS-EFF/efficiency had the most number of supporting studies, followed by REs and AFG. Although evidence for different predictors of RIIs varied according to the RII and study population, there is good evidence that older age, lower prerehabilitation functional status and cognitive impairment are predictive of poorer AFG, REs and REy.
Conclusions: 5 RIIs have been developed in the past two decades as composite rehabilitation outcome measures controlling premorbid and prerehabilitation functional status, rate of functional improvement, each with varying levels of evidence for its predictors. To address the issue of multiple names for the same RII, a new nomenclature system is proposed to harmonise the names based on common mathematical formula and a first-named basis.

ARTICLE SUMMARY

Strengths and limitations of this study

- Use of only one citation database for our literature search. Our literature search was limited to only articles in English due to the high cost of technical translations as well as the validity of how these rehabilitation impact indices (RIIs) were recorded.
- It is the first rehabilitation literature to methodically review all RIIs available based on their formula for calculation. It proposes a nomenclature system to harmonise the names of RIIs across the rehabilitation discipline based on a rational first-named basis.
- Evidence of independent predictors accessed in these RIIs were applied over a wide range of medical conditions and study populations.

INTRODUCTION

Little is known about composite indices of rehabilitation outcomes and the effects of sociodemographic factors and comorbidities on these indices. Thus, there is a need to (1) identify and characterise robust rehabilitation impact indices (RIIs) that can be measured across sites and settings for comparative effectiveness research, and (2) determine the key predictors of these RIIs so that the former can be adjusted for meaningful evaluation across sites and settings.

Currently, many studies in rehabilitation use the final functional status as the outcome measure after adjusting for the participant's initial functional status. However, both were highly correlated resulting in most variation in multivariate analysis being accounted by initial functional status.[1] Moreover, the final functional status does not consider speed of functional recovery or achievement of rehabilitation potential both of which are important in quality of care.[2 3] Researchers have devised several RIIs that account for baseline functional status. However, these RIIs have been given different names although they share the same mathematical formula, which is inconsistent and confusing. Moreover, the independent predictors of RIIs have never been systematically identified for the wide range of conditions requiring rehabilitation. Hence, we performed a systematic review to (1) identify all available RIIs and their synonyms, and categorise them according to mathematical formula, (2) identify and assess the evidence for independent predictors of each RII, and (3) propose a nomenclature system to harmonise the terminology of RIIs.

METHODS

We conducted this review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews.[4]

To achieve the first two aims of the study, we conducted the systematic review in two stages. The first stage was to identify all available RIIs and categorise them according to the same mathematical formula but under different names. For example, the difference between admission and discharge functional scores was termed as *absolute function gain* (AFG), *absolute efficacy* or *total gain*. The second stage was to use these different names and report their independent predictors. For example, we used the terms 'absolute function gain', 'absolute efficacy' and 'total gain' to identify all articles using difference between admission and discharge functional scores. RIIs are prospective as they require functional status to be measured across two time points. Hence, to determine the independent predictors of RIIs, we included case–control and cohort studies, and controlled interventional trials that had RIIs as outcomes, and excluded descriptive studies that did not examine factors associated with RIIs. We deemed factors as independent predictors if multivariate analysis was performed. In controlled trials, the intervention was considered a predictive factor.

Studies were identified from PubMed (until 31 December 2011) as the primary citation database to conduct our literature search and reviewed the articles referenced in these primary for secondary literature which may be eligible for our systematic review. Search terms were specific for each RII. For absolute functional gain, we used the search terms 'absolute function gain', 'absolute efficacy' and 'total gain'. For rehabilitation effectiveness (REs), we used the search terms 'rehabilitation effectiveness', 'Montebello Rehabilitation Factor score' and 'relative functional gain'. For rehabilitation efficiency (REy), we used the search terms 'rehabilitation efficiency', 'length-of-stay efficiency' and 'efficiency'. For relative functional efficiency (RFE), we used the search terms 'relative functional efficiency' and 'MRFS efficiency'.

We limited our search to articles in English as the cost of technical translations was beyond our budget. Of note, we did not limit any medical condition (eg, stroke) or study population (eg, elderly) as rehabilitation is a specialty defined by treatment and our primary aim was to study the properties of RIIs in the full range of study populations. The abstracts of all articles retrieved were first screened for use of RIIs, subsequently the full articles were retrieved if they satisfied the criteria described above. Details of the primary articles eligible for the systematic review were extracted and tabulated (see online supplementary tables S1–S3), and their statistically significant ($p<0.05$) independent predictors were identified. Evidence for a factor as a predictor of an RII was deemed to be none if there was no supporting study, weak if there was only one supporting study, fair if there were two supporting studies, moderate if there were three supporting studies and good if there were four or more supporting studies. Similar systems of using number of supporting studies to weigh scientific evidence have been used by previous systematic reviews.[5 6]

We did not perform a meta-analysis of pooled data to generate the overall effect size for each predictor because of the small number of studies available for each predictor after stratification by study population, different functional measures were used across studies which limited pooling of estimates and important data were missing from primary articles which precluded pooling of estimates (eg, CIs). Lastly, we proposed a nomenclature system to harmonise the terminology of RIIs for future use on the basis that the name of the RII should (1) follow the name coined by the first author(s) to define it and (2) be logical and intuitive. This study was exempted from ethics review because it did not involve human participants.

RESULTS

From the first stage of our systematic review, we identified five RIIs used in rehabilitation literature. Figure 1 details the study selection process, including the five RIIs identified and their synonyms, the number of potentially relevant articles retrieved from PubMed, the number of full articles satisfying study eligibility criteria and the final number of articles accessed. For the remaining Results section, we will present mathematical formula for each RII, its synonyms and its independent predictors.

Absolute functional gain/absolute efficacy/total gain

AFG was first coined by Heruti *et al*[7] as the difference in functional measure score before and after rehabilitation. Mathematically, the formula (FIM, functional independence measure; DC, discharge; adm, admission) is as follows:

$$\mathrm{AFG} = \mathrm{DC}(\mathrm{FIM}) - \mathrm{adm}(\mathrm{FIM})$$

Other authors have referred to AFG as absolute (FIM) efficacy or total (FIM) gain.[7–13] After performing a systematic literature search using these names as search terms, we found seven studies which studied predictors for this RII.[7–13] All these studies used FIM as the functional measure. The predictors of poorer AFG/absolute efficacy/total gain stratified by the study population are summarised in table 1 and details are found in online supplementary table S1.

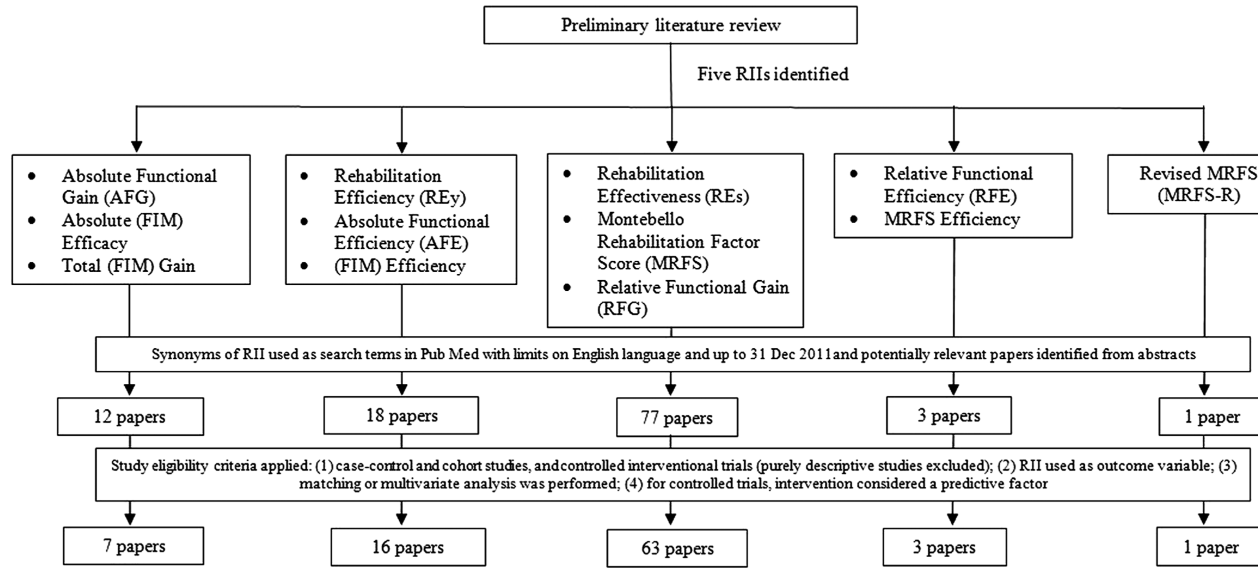

Figure 1 Study selection process for the five rehabilitation impact indices (RIIs) identified.

From table 1, independent predictors of poorer AFG/absolute efficacy/total gain are older age,[11 13] lower prerehabilitation functional status,[11] cognitive impairment,[7 9–11] non-treatment with thrombolysis[13] and greater neurological impairment.[13] The independent predictors were supported by stroke (2 studies), post-hip-fracture arthroplasty (2 studies) and the elderly (1 study).

Rehabilitation effectiveness/Montebello Rehabilitation Factor Score/

Relative functional gain

REs was a concept first suggested by Heinemann *et al*.[1] However, it was Shah *et al* who coined the term rehabilitation effectiveness later in 1990.[14] Expressed as a percentage reflecting the proportion of potential improvement actually achieved during rehabilitation, it can be calculated using the formula (BI, Barthel index; DC, discharge; adm, admission; max, maximum possible score):

$$\text{REs} = \frac{\text{DC(BI or FIM)} - \text{adm(BI or FIM)}}{\text{Max(BI or FIM)} - \text{adm(BI or FIM)}} \times 100\%$$

REs are viewed to be superior to AFG/absolute efficacy/total gain because the latter does not take into account the potential maximal functional improvement. For example, patient A improved his BI score from 20 to 60, whereas patient B improved his BI score from 60 to 100; although both patients improved by 40 BI units, patient A has only reached ((60–20)/(100–20))=40/80=50% of his highest possible level of improvement, whereas patient B has reached his highest possible level of improvement (100%) and is now independent.

REs were renamed by other authors as Montebello Rehabilitation Factor Score (MRFS) in 1994 and *relative functional gain* (RFG) in 2007. After performing a PubMed search, 16 studies were identified.[1 7 9 14–26] The predictors of poorer REs/MRFS/RFG stratified by study population are summarised in table 2 and details are found in online supplementary table S2.

From table 2, independent predictors of poorer REs/MRFS/RFG that have been reported are (1) older age,[1 14 15 24 26] (2) lower prerehabilitation functional status,[1 14 15 17 20 24 26] (3) non-acute hospital admissions,[1] (4) cognitive impairment,[7 9 16 18 20 23 24 26]

Table 1 Summary of independent factors of poorer absolute functional gain (AFG), absolute efficacy or total gain from studies by study population*

Sl. no.	Independent factors of poorer AFG, absolute efficacy or total gain	Stroke	Post-hip-fracture arthroplasty	Elderly
1	Older age	11 13	–	–
2	Lower prerehabilitation functional status	11	–	–
3	Cognitive impairment	11	7 9	10
4	Prior stroke with motor impairment	–	–	–
5	Non-treatment with thrombolysis	13	–	–
6	Greater neurological impairment	13	–	–

*Article reference numbers in cells.

Table 2 Summary of independent factors of poorer rehabilitation effectiveness (REs) or Montebello Rehabilitation Factor Score (MRFS) or relative functional gain (RFG) from studies by study population*

Sl. no.	Independent factors of poorer REs/MRFS/RFG	Stroke	Post-hip-fracture arthroplasty	Elderly	Gait disorders
1	Older age	1 14 15 24 26		–	–
2	Lower prerehabilitation functional status	1 14 15 17 24 26	20 22	–	–
3	Non-acute hospital admissions	1	–	–	–
4	Cognitive impairment	16 24 26	7 9 18 20	23	–
5	Urinary incontinence	14	–	23	–
6	Myocardial infarction	1	–	–	–
7	Longer 'stroke onset to admission into rehabilitation unit' time	14 26	–	–	–
8	Longer 'admission to unit to start of rehabilitation' time	14	–	–	–
9	Poor adherence to clinical practice guidelines	17	–	–	–
10	Orthogeriatric setting	–	18	–	–
11	Subcortical vascular lesions	–	–	–	21
12	Shorter length of stay	26	–	23	–
13	Lower body mass index	–	–	23	–
14	Unilateral spatial neglect	25	–	–	–
15	Female gender	26	–	–	–
16	Malay (vs Chinese) ethnicity	26	–	–	–
17	Caregiver availability	26	–	–	–
18	Ischaemic (vs haemorrhagic) stroke	26	–	–	–
19	Users of psychotropic medication	19	–	–	–
20	Territory of stroke	17	–	–	–
21	Prior stroke	–	22	–	–

*Article reference numbers in cells.

(5) urinary incontinence,[14 23] (6) myocardial infarction[1] (7) longer 'stroke onset to admission into rehabilitation unit' time,[14 26] (8) longer 'admission to unit to start of rehabilitation' time,[14] (9) poor adherence to clinical practice guidelines,[17] (10) territory of stroke,[17] (11) orthogeriatric setting (as compared with a two-step model of orthopaedic surgery followed by transfer to a geriatric rehabilitation facility),[18] (12) users of psychology medications,[19] (13) subcortical vascular lesions,[21] (14) prior episode of stroke,[22] (15) lower body mass index,[23] (16) unilateral spatial neglect,[25] (17) female gender,[26] (18) Malay (vs Chinese) ethnicity,[26] (19) caregiver availability,[26] (20) infarct (vs haemorrhage) stroke[26] and (21) shorter length of stay (LOS).[23 26] The independent predictors of REs/MRFS/RFG were supported by stroke (9 studies), post-hip-fracture arthroplasty (5 studies), elderly (1 study) and gait disorders (1 study). Overall, the evidence for older age (5 studies), lower prerehabilitation functional status (8 studies) and cognitive impairment (8 studies) as predictors of poorer REs/MRFS was strong.

Rehabilitation efficiency/Length of stay-efficiency/efficiency

The concept of REy was also first suggested by Heinemann *et al*[1] using the BI. Later, Shah *et al*[14] renamed this concept to REy. It can be regarded as the average increase in the score of a functional assessment tool per day and is calculated using the following formula (where DC, discharge; adm, admission; date, date of functional assessment scoring):

$$\text{REy} = \frac{\text{DC(BI or FIM)} - \text{adm(BI or FIM)}}{\text{DateDC} - \text{dateadm}}$$

REy is also known as LOS-efficiency (LOS-EFF) and FIM efficiency. Compared with REs/MRFS/RFG, there are many more studies which have used REy/LOS-EFF/efficiency with 63 studies examining predictors of this RII.[1 7 13–15 25–82] The predictors of poorer REy/LOS-EFF/efficiency stratified by study population are summarised in table 3. The details of each study reporting REy/LOS-EFF/efficiency are found in the online supplementary table S3. There were four pairs of studies which were potentially duplicate publications: (Lin[43] and Lin *et al*[44]; Yu and Richmond[58] and Yu *et al*[59]; Vincent *et al*[64] and Vincent *et al*[67]; Vincent *et al*[65] and Vincent *et al*[66]; see online supplementary table S3). Only the last three pairs of studies reported independent predictors of REy/LOS-EFF/efficiency (table 3). We chose to treat these studies as separate original studies as we could not be sure whether they were duplicate publications.

From table 3, the independent predictors of REy/LOS-EFF/efficiency that have been reported are (1) admissions from sources other than home,[1] (2) older age,[14 15 33 58 59 74 80] (3) lower prerehabilitation

Table 3. Summary of independent factors of poorer rehabilitation efficiency (REy) or length-of-stay efficiency (LOS-EFF) or Functional Independence Measure (FIM) Efficiency by study population*

S/No.	Independent factors of poorer REy/LOS Efficiency/FIM Efficiency	Stroke	Post hip fracture arthroplasty	Elderly	Heterogeneous	Brain tumor	Brain injury	Spinal cord injury	Encephalitis	Hemo dialysis	Knee arthroplasty
1.	Admissions from sources other than home	1	–	–	–	–	–	–	–	–	–
2.	Older age	14 15 80	74	58† 59†	–	–	–	33	–	–	–
3.	Lower pre-rehabilitation functional status	14 15 80	74	47 58† 59†	–	–	–	–	–	–	–
4.	Ischemic (vs. hemorrhagic) stroke	26 28	–	–	–	–	–	–	–	–	–
5.	Depression	34 42	54	–	–	–	–	–	–	–	–
6.	Cognitive impairment	26	7 54	–	–	–	–	–	–	–	–
7.	Poorer balance	–	–	–	30	–	–	–	–	–	–
8.	Heterotopic ossification on triple-phase bone scan (vs. none)	–	–	–	–	–	35	–	–	–	–
9.	Non-traumatic (vs. traumatic) spinal cord injury	–	–	–	–	–	–	38	–	–	–
10.	Encephalitis (vs. traumatic brain injury or stroke)	–	–	–	–	–	–	–	39	–	–
11.	Longer length of stay	15 26	–	–	–	–	–	–	–	–	–
12.	Direct admission from emergency ward (vs. indirect admission via general medical ward)	41	–	–	–	–	–	–	–	–	–
13.	Not receiving radiation therapy during rehabilitation (vs. receiving) in brain tumor patients	–	–	–	–	45	–	–	–	–	–
14.	Recurrent (vs. first diagnosis) in brain tumor patients	–	–	–	–	45	–	–	–	–	–
15.	Greater co-morbidity burden	–	71	47	–	–	–	–	–	–	–
16.	Spinal stenosis-induced (vs. traumatic) spinal cord injury	–	–	–	–	–	–	49	–	–	–
17.	Japan (vs. USA)	50	–	–	–	–	–	–	–	–	–
18.	Right hemispheric stroke	51	–	–	–	–	–	–	–	–	–
19.	Greater neurological impairment	51 79	–	–	–	–	–	–	–	–	–
20.	Dialysis (vs. non-dialysis) patients	–	–	–	–	–	–	–	–	53	–
21.	Program to reduce conflicts between hemodialysis and therapy sessions	–	–	–	–	–	–	–	–	56	–
22.	Extremes of dependency	57 58	–	–	–	–	63	–	–	–	–
23.	Discharge to nursing facility (vs. home)	60 61	–	–	–	–	–	–	–	–	–
24.	Lower haemoglobin levels	–	–	–	–	–	–	–	–	–	61

Continued

Table 3. Continued

S/No.	Independent factors of poorer REy/LOS Efficiency/FIM Efficiency	Stroke	Post hip fracture arthroplasty	Elderly	Heterogeneous	Brain tumor	Brain injury	Spinal cord injury	Encephalitis	Hemo dialysis	Knee arthroplasty
25.	Longer 'stroke onset to admission into rehabilitation unit' time	26 51 62	–	–	–	–	–	–	–	–	–
26.	Revision (vs. primary) total hip arthroplasty	–	64†	–	–	–	–	–	–	–	–
27.	Revision (vs. primary) total knee arthroplasty	–	–	–	–	–	–	–	–	–	65† 66† 72
28.	Female gender	–	67†	–	–	–	–	–	–	–	65†
29.	Aortic aneurysm repair induced (vs. traumatic) spinal cord injury	–	–	–	–	–	–	68	–	–	–
30.	Principal disability diagnosis (in order of decreasing FIM efficiency: traumatic brain injury, stroke, spinal cord injury, amputations and pulmonary conditions)	–	–	–	70	–	–	–	–	–	–
31.	Extremes of body-mass index	–	71	–	–	–	–	–	–	–	–
32.	Primary (vs. co-morbid) debility diagnosis	–	–	73	–	–	–	–	–	–	–
33.	Hispanic and black (vs. white) ethnicity	74	–	–	–	–	–	–	–	–	–
34.	Lower staff to patient ratio	76	–	–	–	–	–	–	–	–	–
35.	Neglect	25 79	–	–	–	–	–	–	–	–	–
36.	Non-treatment with thrombolysis	13	–	–	–	–	–	–	–	–	–
37.	Diabetes mellitus	–	80	–	–	–	–	–	–	–	–
38.	Medications that predispose to falls	–	80	–	–	–	–	–	–	–	–
39.	Malay (vs. Chinese) ethnicity	26	–	–	–	–	–	–	–	–	–
40.	Caregiver availability (vs. no caregiver)	26	–	–	–	–	–	–	–	–	–
41.	Higher pre-rehabilitation functional status	26	–	–	–	–	–	–	–	–	–
42.	Peptic ulcer disease	26	–	–	–	–	–	–	–	–	–

* Paper reference numbers in cells
† The following pairs of reference numbers are potentially duplicate publications: [58 & 59], [64 & 67] and [65& 66]

functional status,[14 15 47 58 59 74 80] (4) non-haemorrhagic (vs haemorrhagic) stroke,[26 28] (5) depression,[34 42 54] (6) cognitive impairment,[7 26 54] (7) poorer balance,[30] (8) heterotopic ossification on triple-phase bone scan (vs none),[35] (9) non-traumatic (vs traumatic) spinal cord injury,[38] (10) encephalitis (vs traumatic brain injury or stroke),[39] (11) longer LOS,[15 26] (12) direct admission from emergency ward (vs indirect admission via general medical ward),[41] (13) not receiving radiation therapy during rehabilitation (vs receiving) in patients with brain tumour,[45] (14) recurrent (vs first diagnosis) in patients with brain tumour,[45] (15) greater comorbidity burden,[47 71](16) spinal stenosis-induced (vs traumatic) spinal cord injury,[49] (17) Japan (vs USA),[50] (18) right hemispheric stroke,[51 79] (19) greater neurological impairment,[51] (20) patients undergoing dialysis (vs non-dialysis),[53] (21) programme to reduce conflicts between haemodialysis and therapy sessions,[56] (22) extremes of dependency,[57 58 63] (23) discharge to nursing facility (vs home),[60 61] (24) lower haemoglobin levels,[61] (25) longer 'stroke onset to admission into rehabilitation unit' time,[26 51 62](26) revision (vs primary) total hip arthroplasty,[64] (27) revision (vs primary) total knee arthroplasty,[65 66 72] (28) female gender,[65 67] (29) aortic aneurysm repair induced (vs traumatic) spinal cord injury,[68] (30) principal disability diagnosis (in order of decreasing FIM efficiency: traumatic brain injury, stroke, spinal cord injury, amputations and pulmonary conditions),[70] (31) extremes of body mass index,[71] (32) primary (vs comorbid) debility diagnosis,[73] (33) Hispanic and African-American (vs white) ethnicity,[74] (34) lower staff-to-patient ratio,[76] (35) neglect,[25 79] (36) non-treatment with thrombolysis,[13] (37) diabetes mellitus,[80] (38) medications that predispose to falls,[80] (39) Malay (vs Chinese) ethnicity,[26] (40) caregiver availability (vs no caregiver),[26] (41) higher prerehabilitation functional status[26] and (42) peptic ulcer disease.[26] The medical conditions and study populations from which independent predictors of REy/LOS-EFF/efficiency were derived included strokes (21 studies), post-hip-fracture arthroplasty (7 studies), elderly (4 studies), heterogeneous (2 studies), brain tumour (1 study), brain injury (2 studies), spinal cord injury (4 studies), encephalitis (1 study), haemodialysis (2 studies) and knee arthroplasty (4 studies). Overall, the evidence for older age and lower prerehabilitation functional status as predictive of poorer REy/LOS-EFF/efficiency were good with seven (6 if 1 considers Yu and Richmond[58] and Yu *et al*[59] as duplicate publications) studies each reporting this association respectively with most of the studies based on stroke and elderly rehabilitation, a situation similar with REs/MRFS/RFG. The evidence for cognitive impairment being predictive of poorer REy/LOS-EFF/efficiency was weaker when compared with REs/MRFS/RFG (3 vs 8 studies, respectively). Of note, unlike with REs/MRFS/RFG, the evidence for depression being predictive of poorer REy/LOS-EFF/efficiency was stronger (none vs 3 studies, respectively).

Relative functional efficiency/MRFS efficiency

Heruti *et al*[16] defined RFE in 2002 as REs/MRFS/RFG divided by LOS. In the same year, Zwecker *et al*[83] used the term MRFS efficiency to describe the same formula. The formula for RFE/MRFS efficiency using FIM as the functional assessment tool (where DC, discharge; adm, admission; max, maximum possible score) is as follows:

$$\begin{aligned} \mathrm{RFE} &= \frac{\mathrm{DC(BI\,or\,FIM)} - \mathrm{adm(BI\,or\,FIM)}}{\mathrm{Max(BI\,or\,FIM)} - \mathrm{adm(BI\,or\,FIM)}} \times \frac{1}{\mathrm{LOS}} = \frac{\mathrm{REs}}{\mathrm{LOS}} \\ &= \frac{\mathrm{AFG}}{(\mathrm{Max(BI\,or\,FIM)} - \mathrm{adm(BI\,or\,FIM)}) \times \mathrm{LOS}} \end{aligned}$$

Heruti *et al*[16] demonstrated that the RFE/MRFS efficiency was higher in cognitively intact elderly participants (n=79) compared to cognitively impaired elderly participants (n=65) admitted into a geriatric rehabilitation unit but Zwecker *et al*[83] found no associations between RFE/MRFS efficiency and cognitive function. Recently, Toglia *et al*[84] found that the Montreal Cognitive Assessment (MoCA) was predictive of RFE/MRFS efficiency in 72 patients with mild subacute stroke. To date, these are the only three articles so far that have used the RFE/MRFS efficiency index. Further studies are needed to increase the evidence base for predictors of this relatively new RII.

Revised MRFS

In 2007, Press *et al*[85] proposed a new RII: the revised MRFS (MRFS-R). They proposed that the highest possible functional status should not be the maximum score of the functional assessment tool used but the premorbid functional score instead. For example, hypothetical patient A was quite functional with a premorbid functional score (premorbidFIM) of 120 before a fracture; after fracture repair, on admission to the rehabilitation department, patient A's admFIM score dropped to 60. After rehabilitation, patient A's DCFIM rose to 80. In this case, patient A's MRFS was 0.33, as follows:

$$\begin{aligned} \mathrm{MRFS} &= \frac{\mathrm{DCFIM} - \mathrm{admFIM}}{\mathrm{PremorbidFIM} - \mathrm{admFIM}} = \frac{80-60}{120-60} = \frac{20}{60} \\ &= 0.33 \end{aligned}$$

Patient B who was much more dependent before suffering a hip fracture had premorbid functional score (premorbidFIM) of 80. Patient B's admFIM score dropped to 20 after hip fracture and after rehabilitation, patient B's DCFIM score rose to 40. In patient B's case, the MRFS score was also 0.33:

$$\begin{aligned} \mathrm{MRFS} &= \frac{\mathrm{DCFIM} - \mathrm{admFIM}}{\mathrm{PremorbidFIM} - \mathrm{admFIM}} = \frac{40-20}{80-20} = \frac{20}{60} \\ &= 0.33 \end{aligned}$$

As such, according to the MRFS formula, these two patients enjoyed an equal level of rehabilitation success.

However, these two patients are different as patient B started with a poorer premorbid functional status than patient A. As such, Press *et al* proposed a revised MRFS which adjusts the MRFS to make it more relevant to clinical practice by changing the calculation from an absolute to a relative one and using the premorbid functional score as the highest possible functional status attainable, as follows:

$$\mathrm{MRFS-R} = \frac{(\mathrm{DCFIM} - \mathrm{admFIM})/\mathrm{DCFIM}}{(\mathrm{PremorbidFIM} - \mathrm{admFIM})/\mathrm{premorbidFIM}} = \frac{\mathrm{MRFS}/\mathrm{DCFIM}}{\mathrm{premorbidFIM}}$$

Using this new index, patient A's MRFS-R would be 0.5, as follows:

$$\mathrm{MRFS-R} = \frac{(\mathrm{DCFIM} - \mathrm{admFIM})/\mathrm{DCFIM}}{(\mathrm{PremorbidFIM} - \mathrm{admFIM})/\mathrm{premorbidFIM}} = \frac{(80-60)/80}{(120-60)/120} = \frac{20/80}{60/120} = \frac{0.25}{0.5} = 0.5$$

Patient B's MRFS-R score would be higher at 0.67, as follows:

$$\mathrm{MRFS-R} = \frac{(\mathrm{DCFIM} - \mathrm{admFIM})/\mathrm{DCFIM}}{(\mathrm{PremorbidFIM} - \mathrm{admFIM})/\mathrm{premorbidFIM}} = \frac{(40-20)/40}{(80-20)/80} = \frac{20/40}{60/80} = \frac{0.5}{0.75} = 0.67$$

Press *et al* assert that patient B realised his/her rehabilitation potential more than patient A and that the MRFS-R is a more useful way to quantify the differences. In the same article, Press *et al*[85] compared the MRFS-R with MRFS and found that they were very highly correlated (r = 0.99, p<0.01). Nevertheless, in a linear regression model with MMSE, LOS and Severity Index of Cumulative Illness Rating Scale for Geriatrics as independent factors, they found the adjusted R^2 for MRFS-R was higher than with MRFS as the dependent variable (0.16 vs 0.12), suggesting that the MRFS-R accounted for more variance in the similar model than MRFS. As this is the first and currently only article that has used MRFS-R, more studies are needed to increase the evidence base for predictors of this new RII as well.

DISCUSSION

Increasingly complex RIIs have been developed in the past decade in response to the need to create composite summative measures that control for premorbid and prerehabilitation functional status, and rate of functional improvement. The current RIIs available in increasing complexity are: (1) AFG, (2) REs, (3) REy, (4) relative rehabilitation efficiency (RREy) and (5) relative rehabilitation effectiveness (RREs). On the basis of current literature, more studies have used REy than REs, and even fewer have used AFG, RREy or RREs. Thus, the number of known predictors is highest for REy than the other RIIs. Although the evidence varies, there is consistent evidence that older age, lower prerehabilitation functional status and cognitive impairment are predictive of poorer AFG, REs and REy, particularly in stroke and post-hip-fracture arthroplasty rehabilitation.

One of the possible reasons why few studies have used AFG as an RII could be that AFG does not take into account the potential maximal functional improvement like REs and RREs. Another reason could be that AFG does not consider the rate of functional improvement per unit time like REy and RREy. It is also worthwhile to note that although Heruti *et al*'s[7] study found associations between cognitive impairment and REs, it did not find any such association with AFG, supporting the superiority of REs as an RII over AFG.

Most researchers use LOS for a hospital stay as the denominator for REy and RREy instead of the number of days between first and final functional assessment scoring. This is acceptable provided the functional scoring is performed close to the date of admission and discharge. However, if the first functional measurement was performed many days after admission or the last functional assessment was performed many days before date of discharge, REy and RREy may be spuriously high if LOS was used in the denominator. Hence, it may be more accurate to use the number of days between the date of first and last functional measurement as the denominator for REy instead of LOS, as conducted by Koh *et al*.[26] In fact, it was because Koh *et al* used time between first and last functional assessment in their study that they were able to demonstrate that LOS was an independent predictor of REy and not the result of statistical singularity arising from LOS being the denominator of REy.

Three RIIs use the variable 'maximal score attainable' (ie, max (BI or FIM)): REs, RREs and RREy. Some studies use the maximum score of the functional measurement tool (eg, 100 for BI and 126 for FIM), whereas other studies use the premorbid functional level of the patient (ie, prior to disabling event that necessitated rehabilitation, like stroke or hip fracture). The proponents for the latter argue that premorbid functional status is more appropriate because it is more meaningful to the patient and a person's function rarely improves beyond their premorbid functional status. However, there are disadvantages in using premorbid functional status as the 'maximal score attainable'. First, premorbid functional data are often not available as patients often present in acute settings already disabled from a stroke or hip fracture. Hence, premorbid functional data are often collected retrospectively from patient or caregiver and is vulnerable to recall bias. Second, studies have shown that persons can still improve their functional status months to years after their acute disabling event with rehabilitation, suggesting that one's premorbid functional status is not necessarily their maximal

Table 4. Proposed harmonized nomenclature system for rehabilitation indices

S/No.	Current Names	Formula*	Proposed Standard Name
1.	▶ Absolute Functional Gain (AFG) ▶ Absolute (FIM) Efficacy ▶ Total (FIM) Gain	$FIM_{DC} - FIM_{Adm}$	Absolute Functional Gain (AFG)
2.	▶ Rehabilitation Effectiveness (REs) ▶ Montebello Rehabilitation Factor Score (MRFS) ▶ Relative Functional Gain (RFG)	$\frac{FIM_{DC} - FIM_{Adm}}{FIM_{Max} - FIM_{Adm}}$	Rehabilitation Effectiveness (REs), prefixed by functional measure used (e.g. FIM effectiveness, BI effectiveness)
3.	▶ Rehabilitation Efficiency (REy) ▶ Length-of-Stay Efficiency (LOS-EFF) ▶ (FIM) Efficiency	$\frac{FIM_{DC} - FIM_{Adm}}{LOS}$	Rehabilitation Efficiency (REy), prefixed by functional measure used (e.g. FIM efficiency, BI efficiency)
4.	▶ Relative Functional Efficiency (RFE) ▶ MRFS Efficiency	$\frac{FIM_{DC} - FIM_{Adm}}{(FIM_{Max} - FIM_{Adm}) X\ LOS}$	MRFS Efficiency
5.	Revised MRFS (MRFS-R)	$\frac{(FIM_{DC} - FIM_{Adm})/FIM_{DC}}{(FIM_{Max} - FIM_{Adm})/\ FIM_{Max}}$	Revised MRFS (MRFS-R)

* FIM=Functional Independence Measure; DC=Discharge; Adm=Admission; Max=Maximum possible score, LOS=Length of Stay

functional status attainable.[86–88] Lastly, by fixing max (BI or FIM) as the maximum score of activities of daily living measure used, rehabilitation indices become standardised which is important when comparing across studies, sites or time. We recommend that users of RIIs that contain the variable max (BI or FIM) clearly state in their publications which 'maximal score attainable' they used (ie, maximum score of functional measure or premorbid functional status).

It is also noteworthy that there may be trade-off relationships between RIIs with respect to certain independent predictors. Koh *et al*[26] found that a shorter LOS and poorer prerehabilitation functional status was predictive of poorer REs, but longer LOS and better prerehabilitation functional status was predictive of poorer REy. The authors also demonstrated a trade-off relationship between REs and REy with respect to LOS and prerehabilitation functional status, and identified the ideal range of LOS and prerehabilitation functional status which optimised REs and REy.

Having the same RII with different synonyms is confusing and limits dissemination of results in the international research community, especially within the multidisciplinary field of rehabilitation. To standardise the terminology of RIIs with the same mathematical formula, we propose a harmonised nomenclature system for RIIs on the basis that the name for the RII should follow the name coined by the first author(s) to define it, and be logical and intuitive, as detailed in table 4. While subject to international acceptance, we feel that our harmonised nomenclature system for RIIs is fairer to the authors who first named it and more easily understood.

A limitation in our study was the use of only one citation database for our literature search. However, we felt that this was sufficient as a high percentage of healthcare, medical and rehabilitation articles would be archived in this database. Another limitation of our qualitative systematic review was that it would underidentify predictors of RIIs compared to a quantitative one (ie, a meta-analysis) as the latter would have greater power to achieve statistical significance due to larger sample sizes from pooling of studies. Another limitation was that our literature search was limited to only articles in English due to the high cost of technical translations. Another limitation is the validity of how these rehabilitation indices were recorded. As the FIM and the Barthel index generate ordinal data, it should not be treated as interval numbers and factor analysis should be used to group related measures together. Factor analyses have consistently shown that the FIM comprises two separate factors (a motor and a cognitive factor),[87] and Rasch analysis had suggested that FIM scores should use a transformation to convert ordinal data into interval data.[88 89] Thus, the raw ordinal scores should not be summed into a single total, and the above mathematical manipulations (subtraction or division) of rehabilitation indices (table 4) may not be valid. In addition, although FIM and BI have recognised floor/ceiling effects,[89–93] only three studies specifically reported extremes of dependency predicting FIM efficiency (Gagnon *et al*,[57] Yu *et al*[59] and Turner-Strokes *et al*[63]; table 3), which may suggest reporting bias. However, we feel that it could be because most of the studies have either not reached extremes of dependency or authors may not have checked for extremes in the first place. For example, in Turner-Strokes *et al*'s article, the study population was patients with severe acquired brain injury which ranged from the severely functionally impaired to those who recovered well. The literature search was also only conducted by one author (GCK) although the data extraction and analysis were verified by the other three authors, independently. We also acknowledge that our system of weighing the level of evidence for predictors of RIIs based on number of supporting articles was qualitative and arbitrary. Despite these study limitations, this systematic review is the first in rehabilitation literature to methodically review all RIIs available based on their common formula for calculation, assess the evidence for independent predictors of these RIIs applied over a wide range of medical conditions and study populations, and propose a nomenclature system to harmonise the names of RIIs across the rehabilitation discipline based on a rational first-named basis.

CONCLUSIONS

In conclusion, there are many RIIs reported in the literature and they include AFG, REs, REy, RREy and RREs, with REy having the most number of studies using it as an outcome measure and hence, having the strongest evidence for its predictors. Although the evidence for different predictors of RIIs varies according to the RII, medical condition and study population, there is good evidence that older age, lower prerehabilitation functional status and cognitive impairment are predictive of poorer AFG, REs and REy. A new nomenclature system is proposed to harmonise the names of RIIs based on a common mathematical formula and a first-named basis.

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