Article

Global need for physical rehabilitation: systematic analysis from the Global Burden of Disease Study 2017

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Abstract: *Background*: To inform global health policies and resources planning, this paper analyzes evolving trends in physical rehabilitation needs, using data on Years Lived with Disability (YLDs) from the Global Burden of Disease Study (GBD) 2017. *Methods*: Secondary analysis of how YLDs from conditions amenable to physical rehabilitation have evolved from 1990 to 2017, for the world and across countries of varying income levels. Linear regression analyses were used. *Results*: A 66.2% growth was found in estimated YLD Counts amenable to physical rehabilitation: a significant and linear growth of more than 5.1 billion YLDs per year (99%CI: 4.8-5.4; r^2=0.99). Low-income countries more than doubled (111.5% growth) their YLD Counts amenable to physical rehabilitation since 1990. YLD Rates per 100,000 people and the percentage of YLDs amenable to physical rehabilitation also grew significantly over time, across locations (all $p>0.05$). Finally, only in high-income countries Age-standardized YLD Rates significantly decreased ($p< 0.01$; r^2=0.86). *Conclusions*: Physical rehabilitation needs have been growing significantly in absolute, per-capita and in percentage of total YLDs, globally and across countries of varying income level. In absolute terms, growths were higher in lower income countries, wherein rehabilitation is under-resourced.

Keywords: Rehabilitation; Global Health; Disability; Global Burden of Disease; Health Services Needs and Demand

1. Introduction

Worldwide, rehabilitation needs are growing in tandem with global population growth, population aging seen in many countries, and higher survival rates for people with severe health conditions and disability [1-3]. However, to our knowledge, there is no up-to-date, systematic analysis quantifying worldwide epidemiological trends for the whole set of health conditions amenable to physical rehabilitation. In this paper, we analyze how the global needs for physical rehabilitation have evolved from 1990 to 2017, using data from the Global Burden of Disease Study (GBD) 2017.

The GBD study, which has incorporated data since 1990, is the most comprehensive global epidemiological study to date. It combines data from best available sources (e.g., scientific literature,

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official statistics from ministries of health, household surveys, vital registries, hospital data, claims data [4,5]), processed with increasingly sophisticated modelling approaches (e.g. a continuously updated Bayesian meta-regression tool) to provide rigorous global, regional, and national estimates of relevant population health. The data sources used to ground the estimates are colossal and have increased for each cycle of the GBD study. Most recently, the GBD 2017 used a total of 15,449 scientific literature sources (6.5% and 47,4% more than the GBD 2106 and GBD 2015 cycles, respectively), 21,100 sources of epidemiological surveillance data (12.3% and 49.9% more than GDB 2016 and GBD 2015, respectively), and data from an additional 148,842,107 hospital admissions globally, bringing the total number of admissions that inform GBD estimation to more than 2.6 billion [5,6].

For the first time in the study's history, the GBD 2017 reports data on injuries in terms of their nature or consequence (e.g. hip fracture or spinal cord injury), in addition to and apart from their cause (e.g. falls, road injuries, interpersonal violence) [6]. That new facility is particularly germane to the planning of services and resources in physical rehabilitation.

Others have used GBD study data to examine rehabilitation needs [7,8]. In the more recent example, the World Health Organization (WHO) used the GBD 2015 to examine worldwide needs for mental and physical rehabilitation. They found a 17.6% increase from 2005 to 2015 in Years Lived Disability (YLDs) for health conditions associated with severe disability, and that a remarkable 75% of the total world's YLDs in 2015 came from health conditions amenable to rehabilitation [7]. However, the WHO study did not examine physical rehabilitation needs distinct from the rehabilitation of mental health conditions. Moreover, health conditions with mild disability weights were not considered.

In addition to that WHO's analysis, a number of studies have used GBD data to examine particular conditions amenable to physical rehabilitation, such as injuries (i.e. their causes) [9], musculoskeletal conditions [10,11], neurological disorders [12,13], stroke [14], cardiovascular diseases [15], chronic respiratory diseases [16], cancer [17], or HIV [18]. However, to our knowledge, no study has used current GBD data to examine YLDs and potential needs for rehabilitation for the broad spectrum of conditions amenable to physical rehabilitation.

Using publicly available data from the GBD 2017, this paper aims to provide a systematic global analysis of YLDs for the combined set of health conditions amenable to physical rehabilitation, and specifically answer the following study questions:

- How many are the estimated world's YLDs, including per-capita, age-standardized rates, amenable to physical rehabilitation in 2017?
- What is the percentage of world's YLDs amenable to physical rehabilitation relative to total YLDs.
- Did any of these estimates have changed significantly over time (e.g. since 1990)? If so, by how much? And finally;
- Did any of those trends differ across countries of varying income levels?

The answer to these questions would provide valuable benchmarks to inform global and local health and rehabilitation policies, research, and advocacy. Moreover, such findings could provide direction to funding priorities, as well as timely information for health system planning and strengthening activities, including for determining needs for physical rehabilitation services, as a mean to allocate resources accordingly.

2. Methods

2.1. Study design

Systematic, secondary analysis of public-domain data from the GBD 2017, extracted from the freely-available web platform: the Global Health Data Exchange tool (http://ghdx.healthdata.org/gbd-results-tool).

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2.2. Data selection

From the list of YLD "causes" (i.e. underlying health conditions), "impairments" (i.e. consequences of injury or diseases that have more than one diagnostic cause) and "injuries" (i.e. the nature of the injury), the authors selected those deemed likely to benefit (i.e., amenable to) from physical rehabilitation. Given that YLDs from "causes" are collective exhaustive, to avoid double counting we do not cumulatively select YLDs from Injuries as a "cause", but only YLDs from the nature of the injury. Also, YLDs from "impairments" were limited to those not coming from "causes" we had already selected.

We found no global standard to inform which health conditions are amenable to physical rehabilitation; so, in determining which conditions to focus on as potentially benefitting from physical rehabilitation, we relied on the following: previous works using GBD data for rehabilitation [7,8,19]; papers analyzing publication trends in physical rehabilitation and physical therapy across conditions [20-22]; and finally on the below working definition [23-28].

Physical rehabilitation uses health-based approaches to optimize physical function and participation in persons with physical impairments (e.g. mobility) or symptoms (e.g. low back pain) that are amenable to recovery, prevention, or management from physical rehabilitation services, facilities or providers (e.g. physical or occupational therapists).

From this definition, we excluded rehabilitation of people with oral, mental health, substance abuse disorders, intellectual or sensory impairments per se, although partial overlap often occurs across different forms of rehabilitative interventions for those conditions. Table 1 provides the full list of the included conditions.

Table 1. List of GBD causes, injuries and impairments selected as amenable to physical rehabilitation.

Causes
Communicable, Maternal, Neonatal or Nutritional:
• HIV/AIDs
• Leprosy; Zika
• Meningitis, Encephalitis; Tetanus
• Neonatal Disorders
Non-communicable
• Neoplasms
• Cardiovascular Diseases (includes Stroke)
• Chronic Respiratory Diseases
• Neurological disorders, except Epilepsy and Migraine (tension-type headaches included)
• Autism Spectrum Disorder
• Musculoskeletal conditions (includes Low back Pain and Neck Pain)
• Congenital Birth Defects, except Urogenital and Digestive
Injuries (nature of the)
• Amputations
• Burns
• Fractures, except skull
• Head Injuries
• Spinal Injuries
• Minor Injuries: muscle and tendon injuries, including sprains and strains lesser dislocations; Open wound(s)
• Dislocation of hip; Dislocation of knee; and Dislocation of shoulder
• Asphyxiation
• Crush injury; Nerve Injury; Severe Chest Injury
• Multiple fractures, dislocations, crashes, wounds, pains, and strains
Impairments (from the non-selected "causes" combined)
• Hearth Failure
• Guillain-Barré Syndrome

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Of note, within the application of the working definition and exclusion criteria, 'dubious' selection decisions existed. For example, in Autism Spectrum Disorder, psychosocial disfunction and rehabilitative approaches are often dominant, but sensory-processing and motor impairments are prevalent and might benefit from physical rehabilitation, as well [29-35]. In this context, we included this condition, although this choice may lead to an over-estimation of physical rehabilitation needs. By contrast, we excluded some other health conditions, e.g. those for which the benefit of rehabilitation has not been fully established yet. To reduce the bias towards over- vs under-estimation resulting from 'dubious' selection decisions, a priori evidence-based reasoning was established for the conjunct of 'dubious' selection decisions (see **Appendix 1** [29-79]).

Indeed, toward informing these decisions, we searched PubMed primarily for aggregated evidence, preferably systematic reviews, on the effect of physical rehabilitation approaches (e.g. physical therapy, cardiac rehabilitation, pulmonary rehabilitation) on each type of condition we identified as potentially "dubious" for inclusion. We further gave priority to locating and selecting systematic reviews from Cochrane Database of Systematic Reviews, whenever available (i.e. adding "AND "Cochrane Database Syst Rev"[Journal]" to the search approach). As an example, we found that the quantity, quality and strength of the evidence base for cardiac rehabilitation varies across various cardiac conditions [36-42], but strong evidence that cardiac rehabilitation approaches are overall cost-effective [44]. Thus, we included YLDs from all cardiovascular conditions as being amenable to physical rehabilitation. As another example, we did not include any of the maternal, urological or gynecological, even though there is a body of literature pointing that physical therapy can be useful for addressing incontinence and pelvic pain [70,71]. However, we found that underlying evidence base on use of physical therapy for on the chronic pelvic pain and incontinence still is considered insufficient [72,75], and the vast majority of urological and gynecological conditions are not typically treated with physical rehabilitation. In addition, data weren't available in the GBD to identify particular urological/gynecological conditions potentially amenable for rehabilitation, i.e., there are no GBD "impairments" for consequences of such as urological/gynecological conditions such as incontinence or pelvic pain. So, we altogether excluded the maternal, urological or gynecological diseases, even though some might generate YLDs eventually amenable to physical rehabilitation.

2.3. Data extraction:

Data extraction occurred in the early December 2018. As the entire time series is re-estimated in each GBD cycle, the GBD 2017 data supersede that of any previous cycle [6]. Hence, for all the "years" from 1990 to 2017, and for each selected health condition (**table 1**), data was extracted with the following specifications:

Data were extracted only for *YLDs*, i.e. the aggregative measure of the GBD study that focuses exclusively in non-fatal impacts of health conditions. YLDs are the years lived with any short-term or long-term health loss weighted for severity by the disability weights. Concretely, YLDs are computed by combining the estimated prevalence of a health condition with the estimated number of years people typically live with those sequalae, up to the population life expectancy threshold. Importantly, the prevalence of sequalae from each condition is classified by severity levels (e.g. mild, moderate, severe), each one having a respective disability weight [5,6,80,81]. For stroke, for example, disability weights vary from 0.019 for mild sequelae to 0.588 for severe sequalae plus cognition problems, as determined by population preferences in large discrete choice experiments [81]. Details on how YLDs and disability weights are determined, and the current disability weights for all conditions, are provided elsewhere [5,6,81].

In terms of "metrics", we extracted YLDs data for prevalent *number* (i.e. YLD Counts), *rate* (i.e., YLDs per 100 000 people), and *percentage* (i.e. percentage of YLDs for the respective condition among the total number of YLDs). In terms of "age", we extracted YLDs both for *all ages* and *age-standardized* rates – the latter adjusts YLD values for population growth and ageing at the same time. Regarding "location", YLDs data were extracted for the *world*, and for *high*, *upper middle*, *lower middle*, and *low-income* countries, according to the *World Bank Income Levels*.

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All these selected data were imported from the webtool to Excel[a] spreadsheets for data storage, management, and analysis.

2.4. Data analysis

To determine the overall physical rehabilitation needs, we combined (i.e. summed) the YLDs data for all the selected health conditions - within each of the "years", "locations", and "metrics". Percent changes from 1990 to 2017 were also computed for the combined values.

For inferential statistics, first we plotted the entire time series for the combined values. Using visualization and r^2 values of pilot regression models, then we determined which regression model type (i.e. linear, exponential, or logarithmic) best fit the plotted data. Given negligible differences (r^2 values < 0.02), we retained the linear regression option. Linear regression analyses, using the analysis of variance (ANOVA), then were used to test for statistical significance. We used the linear regression analytical approach even for the data that fitted a exponential or logarithmic-type of regression; yet, in those cases, YLD values were log-transformed a priori. We tested for two hierarchical levels of statistical significance: 99 and 95%, respectively.

3. Results

Table 2 shows that, from 1990 to 2017, a 66.2% growth was found in estimated YLD Counts amenable to physical rehabilitation, with a significant and linear growth of more than 5.1 billion YLDs per year (99% CI: 4.8.-5.4; r^2 0.99). While countries from all income levels had significant and linear growths, low-income countries more than doubled (111.5% growth) their YLD Counts amenable to physical rehabilitation for the 28 years time.

Table 2 also shows significant growths in estimated YLD Rates for the same time-period, worldwide and across countries of all income levels. However, for low-income countries the growth was not linear (i.e. best fir in a logarithmic model (r^2=0.5)) and was only significant at a 95% confidence level (p=0.02). Of note, upper middle-income countries had a yearly growth of 42.6 YLDs per 100,000 people (99% CI: 38.1-47.2; r^2=0.96), significantly higher than any of the comparators, i.e. no overlap among the 99% CIs.

On Age-standardized YLD Rates, which adjusted YLDs for population size and ageing, **Table 2** shows that only high-income and lower middle-income countries had a significant change since 1990, but while the latter had a linear growth (99 CI: 0.89-3.78; r^2=0.46), the former a logarithmic decrease (r^2 = 0.86; p< 0.01). Overall, in this metric we observed the smallest magnitude of changes: maximum of 2.7% change from 1990 to 2017.

Finally, Table 2 shows that the percentage of YLDs amenable to physical rehabilitation significantly and linearly increased across locations (all: p< 0.01; minimum r^2=0.87). But while high-income countries had the highest percent value in 2017 (48,6%), low and middle-income countries (LMICs) were growing significantly more - up to 7 times further (99% CIs: 0.19-0.22 vs. 0.02-0.04).

	YLDs amenable to Phys. Rehab.													
	YLD Counts, Billions			YLD Rates (per 100,000 people)				Age-standardized YLD Rates				% of YLDs amenable to phys. rehab. among total YLDs		
		[1990-2017]			[1990-2017]				[1990-2017]				[1990-2017]	
	2017	% change	Linear Regression: r^2; Yearly Growth (99% CI)	2017	% change	Linear Regression: r^2; Yearly Growth (99% CI)	Log Regression Model: (r^2; p value)	2017	% change	Linear Regression: r^2; Yearly Growth (99% CI)	Log Regression Model: (r^2; p value)	2017	% change	Linear Regression: r^2; Yearly Growth (99% CI)
World	343	66.2%	r^2=0.99; 5.1(4.8-5.4)*	4488	17.3%	r^2=0.96; 25.7(23.0-28.4)*	-	4334	-1.0%	-	r^2 = 0.22; p= 0.41	40.2%	9.5%	r^2=0.97; 0.13(0.12-0.15)*
High-Income	79	37.4%	r^2=0.99; 0.8(0.76-8.6)*	6643	15.6%	r^2=0.98; 33.1(30.4-35.8)*	-	4872	-2.7%	-	r^2 = 0.86; p< 0.01*	48.6%	2.2%	r^2=0.87; 0.03(0.02-0.04)*
Upper Middle-Income	123	62.1%	r^2=0.99; 1.8(1.7-1.9)*	4669	29.9%	r^2=0.96; 42.6(38.1-47.2)*	-	4080	-0.6%	r^2 = 0.04; 1.34[(-2.3)-5.0]	-	42.2%	11.4%	r^2=0.97; 0.17(0.15-0.19)*
Lower Middle-Income	119	90.4%	r^2=0.99; 2.10(2.0-2.2)*	3806	17.7%	r^2=0.96; 21.6(19.3-23.8)*	-	4314	1.2%	r^2=0.46; 3.2(0.89-3.78)*	-	35.9%	16.8%	r^2=0.98; 0.2(00.19-0.22)*
Low-Income	21	111.5%	r^2=0.996; 0.39(0.38-0.41)*	3112	4.5%	-	(r^2=0.5; p=.02)**	4276	2.1%	-	r^2= 0.15; p=0.85	32.1%	15.4%	r^2=0.97; 0.16(0.14-0.17)*

Table 2: YLDs amenable to Physical Rehabilitation (Phys. Rehab.) for the World and across countries of varying income level. Linear or Logarithmic (Log) Regression models according to best fit with the data (r^2 values and plot vizualiation). All the data trends fitting into a Linear model also fitted within an Exponential Model (maximum r^2 difference =.012). In those circunstamces, we only retain the Linear Model. Confidence Intervals (CIs) and p values of the regression models computed with ANOVA. In the Log Models, ANOVA was applied over log-transformed YLD estimates. Legend: * Statistically significant at a 99% confidence level; ** Statistically significant at a 95% confidence level.

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4. Discussion

This paper is, to our knowledge, the first systematic, secondary analysis of global physical rehabilitation needs, based on publicly-available data from the most comprehensive source of global epidemiological data to date, i.e. the GBD 2017. In addition to an over 66% global increase in YLD Counts from 1990 to 2017 (5.1 billion additional YLDs per year), we found a 17% increase in YLD Rates, i.e. per population size. Therefore, the growth of YLDs from conditions amenable to physical rehabilitation needs outpaced that of the population. Key for that per-capita growth has been the global population ageing, as the world's Age-Standardized YLD Rates did not significantly change over the studied time-period. As the global population ageing is predicted to endure (e.g. global population with 65 years or more is predicted to double by 2050, while the overall population is expected to grow by less than 30% [82]), global physical rehabilitation needs are likely to continue to grow in tandem, with consequent increased demands for physical rehabilitation.

The growth in needs for physical rehabilitation is particularly troublesome for LMICs. For instance, in low-income countries the YLD Counts more than doubled since 1990, especially due to high fertility rates and population growth, i.e. YLD Rates were growing at a much less pronounced rate. In fact, increases in YLD Counts were inversely proportional to the countries' income levels, such that the greatest increase in needs for physical rehabilitation was found in countries with lower income levels and the least rehabilitation infrastructure. Indeed, rehabilitation resources in many LMICs remain quite limited [7,19,26,83,84]. The WHO estimates that skilled rehabilitation professionals for many LMICs are currently about one-tenth of those required [7]. Hence, many argue it is urgent to take action to supply LMICs with increased resources, [24,26,83-87] and especially so given the higher nominal increases of physical rehabilitation needs.

In addition to resource increases, innovative solutions might be further developed toward increasing access to essential, quality rehabilitation services for locations with suboptimal or unevenly distributed rehabilitation resources. That includes rehabilitation delivered at home, the community or via tele-means - in complement or alternative to more traditional settings-based rehabilitation [43,86,88-93]. Task-shifting to healthcare assistants or team-based community care, especially in LMICs, also remains a venue for future research and development [94].

In low-income countries, we also observed a logarithmic growth in YLD Rates, flattening around the year 2000 (see **Appendix 2** for the graphical representation of the data, page 2). It is possible that global health activities for the Millennium Development Goals, which focused, for example, in preventable neonatal and infectious conditions, have helped controlling the rise in the prevalence of those conditions, and therefore the resulting YLDs in lower income countries [95]. Though, the sequalae (i.e. the disability) from those conditions might not have been addressed as much as its prevalence. For instance, children with complex health conditions and people with HIV/AIDs now increasingly survive in LMICs but with associated disabilities and rehabilitation needs often unmet [84,86,96-99]. In this scenario, granting access to needed rehabilitation, especially in LMICs, is of utmost importance [24,85,87], and justified by the current YLDs data.

Only in high-income countries Age-standardized YLDs were significantly reduced, whereas in LMICs they did not significantly change or have significantly increased since 1990. We hypothesize that the wide implementation of physical rehabilitation services in high-income countries, not in LMICs, has had a contribute. Historically, LMICs' health systems and global health activities have been focused in reducing preventable mortality, while the global burden of non-fatal health losses has been lagging in terms of global health priority, resources, and gains [1,5,6,100]. Fortunately, there is now a global awareness about the need to avert preventable YLDs through appropriate healthcare services, including rehabilitation [5,6,24,101]. Similarly, global health policies are, now, more inclusive of people with disabilities and their rehabilitation needs [87,102,103]. Finally, the evidence of cost-effectiveness of rehabilitation is escalating [104,105]. In this context, our finding that Age-standardized YLDs were significantly reduced in high-income countries, but not in LMICs, can be another indicator of the need to scale up rehabilitation services in LMIC's health systems [24]. Cardiac rehabilitation programs might be a good example, they have been proven cost-effective [105], are

standard in high-income countries, yet barely existent in many LMICs [106-108], even though service delivery models suitable to the LMICs have been developed [109].

Finally, we found the percentage of YLDs amenable to physical rehabilitation significantly and linearly increased across analyzed locations. Furthermore, we observed a trend toward convergence, as the high-income countries had the highest value in 2017, but the growth in LMICs has been significantly higher since 1990. However, even in high-income countries a significant growth has been persisting over time, indicating that the ceiling has not been reached yet in the percentage of YLDs amenable to physical rehabilitation. The higher is that percent value, higher is the expected impact of physical rehabilitation, i.e. in terms of being able to reduce a higher share of the global burden of non-fatal health conditions.

Limitations

The paper's limitations are the following: First, the YLD measure is, at best, a proxy indicator of physical rehabilitation need. For instance, functional data at the population level, e.g. from the Model Disability Survey, and/or other disability statistics, whenever available, might be used in alternative or complement to provide a more comprehensive picture of populations' physical rehabilitation needs [85,110-112]. This limitation notwithstanding, the GBD is the most comprehensive source of global epidemiological data to date, and GBD data are widely used to analyze of the needs for, or benefits from, specific types of healthcare [113-116].

Second, there is no global standard of conditions amenable to physical rehabilitation which we could use for the selection of specific health conditions to include in our analyses. To inform that selection, we relied on previous research on physical rehabilitation, a working definition of physical rehabilitation, and tailored searches on PubMed. Nonetheless, tailored searches conducted on PubMed to identify and help select of health conditions amenable to physical rehabilitation, do not equate to a systematic review itself. For conditions which were particularly uncertain with regards to potential benefits from physical rehabilitation, we employed explicit, a-priori reasoning about the potential trade-offs for over- vs under-estimation of physical rehabilitation needs.

Third, once we partly relied on published evidence to ground selection decisions and our trade-off reasoning, any under-research on the rehabilitation of conditions less common in high-income countries (e.g. tuberculosis, malaria) might have biased that reasoning. It is unknown whether the such putative under-research contributes under-estimate the magnitude of physical rehabilitation needs, especially in lower income countries.

Fourth, we used inferential statistics with YLD estimates, rather than direct data collection with metrics to quantify the nature and degree of physical disability. Moreover, the uncertainty intervals of the underlying YLD estimates could not be computed for our 'combined' values (i.e. the sum of YLDs from all health conditions amenable to physical rehabilitation), although they exist in the public domain for each included condition in isolation [6].

Finally, we focused on evolving trends for overall needs for physical rehabilitation, and did not perform sub-group analyses for specific groups of conditions (e.g. musculoskeletal, neurological, cardiothoracic, etc.) as these have been performed by other groups for using GBD data.

5. Conclusion

This systematic secondary analysis of the GBD 2017 provides global data on current physical rehabilitation needs, and on how those needs evolved since 1990, including across countries of varying income level.

Across locations, physical rehabilitation needs have been growing significantly over time; not only in absolute terms, but also per-capita and in percentage of the total amount of total YLDs. This means that not only physical rehabilitation has been growing, but also that physical rehabilitation is now capable of averting a higher portion of the global burden of disability. The highest absolute growth of physical rehabilitation needs was observed in countries of lower income level, which typically have deprived rehabilitation infrastructure. Finally, only in high-income countries a

significant reduction in age-standardized needs per capita occurred, which can be related to the wider implementation of physical rehabilitation services in these countries.

The use of the comprehensive, up-to-date GBD estimates for the needs-side of the rehabilitation resources-planning equation, albeit imperfect, is a readily-available mean to first highlight, and then help health planners to meet the physical rehabilitation needs of the global population. These needs were found high and increasing, including per-capita, across countries of varying income level.

Supplementary Material: The Appendix 1 provides the rationale and evidence informing on the 'dubious' inclusion decisions, within a trade-off reasoning for the over- & under-estimation of physical rehabilitation needs that might arise from those decisions. The Appendix 2 provides the graphical representation of the data portrayed in table 2.

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