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Review article

Prevalence and economic cost of malnutrition in Italy: A systematic review and metanalysis from the Italian Society of Artificial Nutrition and Metabolism (SINPE)

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ABSTRACT

Objectives: Disease-related malnutrition (DRM) is a major public health issue with dramatic consequences on outcomes. However, in Italy a comprehensive and updated overview on national prevalence, in both the adult and pediatric populations, and its burden on the health care environment, is missing. The aim of this systematic literature review and meta-analysis was to identify and summarize the available evidence regarding the prevalence of DRM in Italy from pediatric to adult and older ages, and to project its global costs on the health care system.

Methods: We performed a systematic literature search for articles on epidemiology of DRM in Italy published up to June 2021. Studies reporting data on the prevalence of DRM in community-dwelling individuals with chronic diseases, nursing home patients, and hospitalized patients (medical, surgery, and oncology patients), were selected for inclusion. Methodological quality of the studies was assessed by two independent reviewers using published criteria. An epidemiologic meta-analysis to obtain an aggregate estimate of prevalence of DRM was performed and a model for estimating the cost of illness, based on the application of epidemiologic results to official national hospitalization data, and attribution of relevant unit costs in the national context was constructed.

Results: Sixty-seven studies reporting on the prevalence of DRM in Italian populations were included in the final selection; meta-analytical pooling yields mean prevalence estimates of about 50% and 30% in adult and pediatric hospitalized populations, respectively, with even higher findings for residents of long-term care facilities. Modeled projections of DRM-attributable yearly economic effects on the Italian health care system exceed 10 billion € in base case analysis, with the most optimistic estimate still exceeding 2.5 billion €.

Conclusion: Although comparable in magnitude to data from previous studies in analogous international settings, the diffusion and effects of DRM in the Italian setting is impressive. Increased awareness of these data and proactive fostering of clinical nutrition services are warranted, as prompt identification and treatment of malnutrition have been shown to effectively improve clinical and economic results.

Introduction

With its total 60,315,000 inhabitants, among which 2,710,000 are <5 y of age and 14,284,000 are >65, Italy is an industrialized country with an increasing population at potential risk for or affected by malnutrition [1].

Several seminal studies have explored the prevalence of malnutrition in different settings. Results have demonstrated variable rates, possibly because of different screening tools adopted by the authors. The largest body of epidemiologic evidence comes from hospitals, where the reported ranges vary from 28% to 73%, depending on the screening tool or the criteria used to diagnose disease-related malnutrition (DRM) and the selected population [2–5], with higher rates in older adults and in specific settings [6,7]. Studies conducted in hospitalized children report a

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prevalence of 6.9% to 25% [8,9]. Data from community-dwelling older individuals and from nursing homes residents show variable prevalence in the range of 5.1% to 37.5% [2,10,11] and of 1.5% to 66.5% [2,12], respectively.

Although it is clear that malnutrition represents a significant health care issue with recognized detrimental consequences on clinical outcomes and on quality of life, to the best of our knowledge no systematic or structured attempt has been conducted to jointly analyze available national data, mostly produced in small populations, nor to estimate the associated costs and consequences on the national health system.

Therefore, the aim of this systematic literature review and meta-analysis was to identify and summarize the available evidence regarding the prevalence of DRM in Italy from pediatric to adult and older ages, and to project its global costs on the health care system.

Albeit no national publication is available on the cost consequences, from the international literature, it is known that malnutrition is associated with an increase in several health care cost items through different intermediate effects, including more frequent admissions and longer hospital stays [13–15], increased susceptibility to infections [16] with an associated increase in antibiotic use and higher management costs for long-term care residents [17]. In the broader perspective of society in general, productivity losses due to both absenteeism and presenteeism heavily contribute to the overall burden of malnutrition. In the present study, we concentrated on hospital costs for a series of reasons, but mainly because of magnitude (predominates over other health care costs) and availability of official statistics on which to elaborate the estimates.

Methods

Systematic review and meta-analysis

On June 30, 2021, EMBASE (Elsevier interface) and MEDLINE (PubMed interface) were searched according to Population, Intervention, Comparator, Outcomes (PICO) criteria using search strings built on key terms ("malnutrition," "failure to thrive,") without restrictions or filters. In a later phase, we further hand-searched bibliographies of relevant publications to identify potential articles missed by the principal search. Search results obtained in EMBASE and MEDLINE were combined to eliminate duplicate records with the Web App Rayyan [18] and/or by manual check.

Articles were considered eligible if reporting results of original studies on the epidemiology of malnutrition in Italian pediatric and/or adult populations in the past 15 y in Italy, unless study design was judged unclear or unsuitable, written in a language other than English and Italian, focused on specific nutritional deficiencies (e.g., vitamin D), or on malnutrition in the obese population.

Two review authors independently screened and selected studies, first based on title and abstract and subsequently on the full text. At the end of each step of the selection process, the investigators compared their results; disagreements were discussed with a third review author, after having consulted the original publication authors for clarification, if necessary, until consensus was reached.

Two review authors independently extracted data from each selected paper into a predefined standardized collection grid: study population, sample size, setting, type of (risk for) malnutrition assessment (tool/score or other criteria), potential bias, and epidemiologic outcomes (incidence/prevalence).

Although a frequent problem, no single universal definition exists for malnutrition, and this is reflected in the availability of several evaluation criteria: for adults, we considered only validated tools and scores (Mini Nutritional Assessment [MNA]/MNA-Short Form [SF], Malnutrition Universal Screening Tool [MUST], Geriatric Nutritional Risk Index [GNRI], Nutrition Risk Screening [NRS] 2002, Subjective Global Assessment [SGA]/SGA-Dialysis Malnutrition Score [DMS], and the Malnutrition-Inflammation Score; see Suppl Table 1 for more details). For the pediatric population, malnutrition prevalence estimates stemming from the assessment of anthropometric measures, alone or in combination with biochemical parameters were included (STRONGkids, body mass index [BMI] z-score, weight for length z-score, height for age z-score length for age z-score, Cole criteria).

Risk of bias (RoB) in individual studies was assessed independently by two review authors using the Joanna Briggs Institute Critical Appraisal Instrument for prevalence studies [19], scored as previously proposed [20] (i.e., 1 point for each domain considered adequate, 0 points for unclear, not applicable, or inadequate).

For the primary analysis (PA), studies were grouped by type of population and by setting. Additional subgroups were identified depending on the type of assessment (tool or other criteria) used in the study and basing on the used assessment tool, undertaking a subgroup analysis, defined as "high-quality analysis" (HQA), considering only studies that determined the prevalence of malnutrition using only specific (risk for) malnutrition indicators (MNA, MNA-SF, MUST score, NRS 2002, and GNRI).

Furthermore, data also were analyzed separately by type of assessment score, dividing those evaluating the risk for malnutrition (i.e., MUST, NRS 2002, GNRI; risk prevalence analysis [RPA]) from malnutrition diagnosis tools (diagnosed prevalence analysis [DPA]).

Meta-analysis was undertaken using a random-effects model conducted with the command metaprop of STATA version 15 (StataCorp, College Station, TX, USA). A pooled prevalence estimate was calculated with 95% confidence interval (CI) for each population considered in the analysis. The random-effects approach was chosen to account for possible heterogeneity in malnutrition prevalence observed in the included studies. Such heterogeneity was assessed using the I^2 statistic, which describes the percentage of variation not due to sampling error across studies. An $I^2 > 75\%$ indicates high heterogeneity [21].

Cost of illness analysis

In this study, we aimed to quantify how DRM effects overall hospital costs by increasing frequency and duration of hospitalizations for underlying diseases. The Italian National Health Service (NHS) reimburses hospitals based on diagnosis-related group (DRG) tariffs; therefore, its expense depends mainly on the number of admissions and only marginally on the length of stay (LOS), which modifies the reimbursed amount only for quite rare over-threshold discharges. On the contrary, higher LOS represents a direct cost excess for the health care provider. This dual effect on hospital expenses led us to consider two perspectives (NHS and hospital) to better describe the different aspects of DRM burden.

Hospital perspective

Cost excess for LOS increases due to DRM has been investigated and recorded by multiple publications. To quantify it, we applied the simple analytical relationship developed by Correia et al. [22] shown in Figure 1, where LOS_i is the higher LOS due to DRM compared with non-malnourished patients, LOS_a is the average overall LOS, Cd is the average daily hospital cost, p is the prevalence of DRM, and n is the number of admitted patients.

A focused literature search has been performed to collect data on LOS_i measured in real clinical practice, primarily focusing on the national context. Given the observational nature of the data we were looking for, particular attention was paid to the handling of confounders to minimize RoB, therefore mean relative LOS was calculated in the base case on data deriving only from studies controlling or adjusting for confounders or both. Alternative *Raw*, *best*, and *worst* scenarios were based on data obtained from all the studies, and minimum and maximal values among low RoB studies, respectively.

Total inpatient days (LOS_a) in Italy for 1 y have been calculated based on National Statistics on Hospital Discharges (SDOs) [23]. The distinction of pediatric and adult inpatient days was based on age-specific codes or, for common DRG codes, on the overall proportion: SDO database reports that 9% of all hospital admissions are pediatric. Similarly, total adult inpatient days have been divided into oncologic, non-oncologic surgical and medical main diagnosis, as defined by the coding.

Average cost of the general ward was estimated based on administrative database analysis by Regional Agency (889€, actualized to 2021) [24].

Alternative scenarios were explored, considering lowest LOS increase among collected data, applied to the lower 95% CI limit of DRM prevalence (defined as *best case*) and highest LOS increase applied to the upper 95% CI limit (*worst case*).

Third-party payer perspective

In Italy, the NHS funds health care providers on a per-admission basis. Thus, any excess in hospitalization rate due to DRM represents an additional cost for the third-party payer. For the present analyses, this was estimated by the equation shown in Figure 2, where ΔH_M is the excess of admissions due to malnutrition, #H is the number of hospital admissions, pGP is DRM prevalence in general population, and IRR is the incremental risk rate of DRM versus GP. This parameter is calculated as odds ratio (OR) of DRM prevalence of admitted patients versus the GP, as estimated in the epidemiologic meta-analysis. The mean annual number of hospital admissions was obtained from the SDO database [23], with focus on ordinary admissions.

To translate excess admissions due to DRM into cost increase for the NHS, the average cost per ordinary admission reported by a recent Association of Italian Pediatric Hospitals (AOPI) analysis [25], resulting in 2,625€ and 2,795€, respectively, has been applied for pediatric and adult patients. Alternative scenarios are based on the low (*best*) and high (*worst*) 95% CI limits of DRM prevalence.

$$\Delta C_{DRM} = \frac{(p * LOSi)}{(p * LOSi) + 1} * n * LOSa * Cd$$

Figure 1. Analytical formula to describe additional cost due to length of stay increment related to disease-related malnutrition [6]

$$\Delta H_M = \frac{(IRR - 1) \times pGP \times \#H}{1 + (IRR - 1) \times pGP}$$

Figure 2. Analytical formula to estimate increase in hospital admissions attributable to disease-related malnutrition.

Results

Systematic review and meta-analysis of malnutrition prevalence

Study selection

The last run of the search strings on June 30, 2021 identified 979 hits from Embase and 1159 hits from PubMed.

After exclusion of duplicates, 1942 hits were screened by three independent reviewers and yielded 87 publications investigating the outcomes of interest. However, 20 studies reported on rare diseases or conditions and were not considered for the subsequent analyses, leaving 67 included studies (Fig. 3) [26–92].

Of these, 58 were conducted with adult and 9 with pediatric populations; malnutrition was assessed mainly with validated tools/scores (57 studies, Supplementary Table 2) and in fewer cases by different criteria (10 studies, Supplementary Table 3).

The average quality of the 67 included studies was moderate to high, with a RoB score of 6.42 (range 4–9). Most included studies employed valid methods for the identification of the condition, appropriate statistical methods, described in detail in study participants and settings, used validated measurement tools and sampled

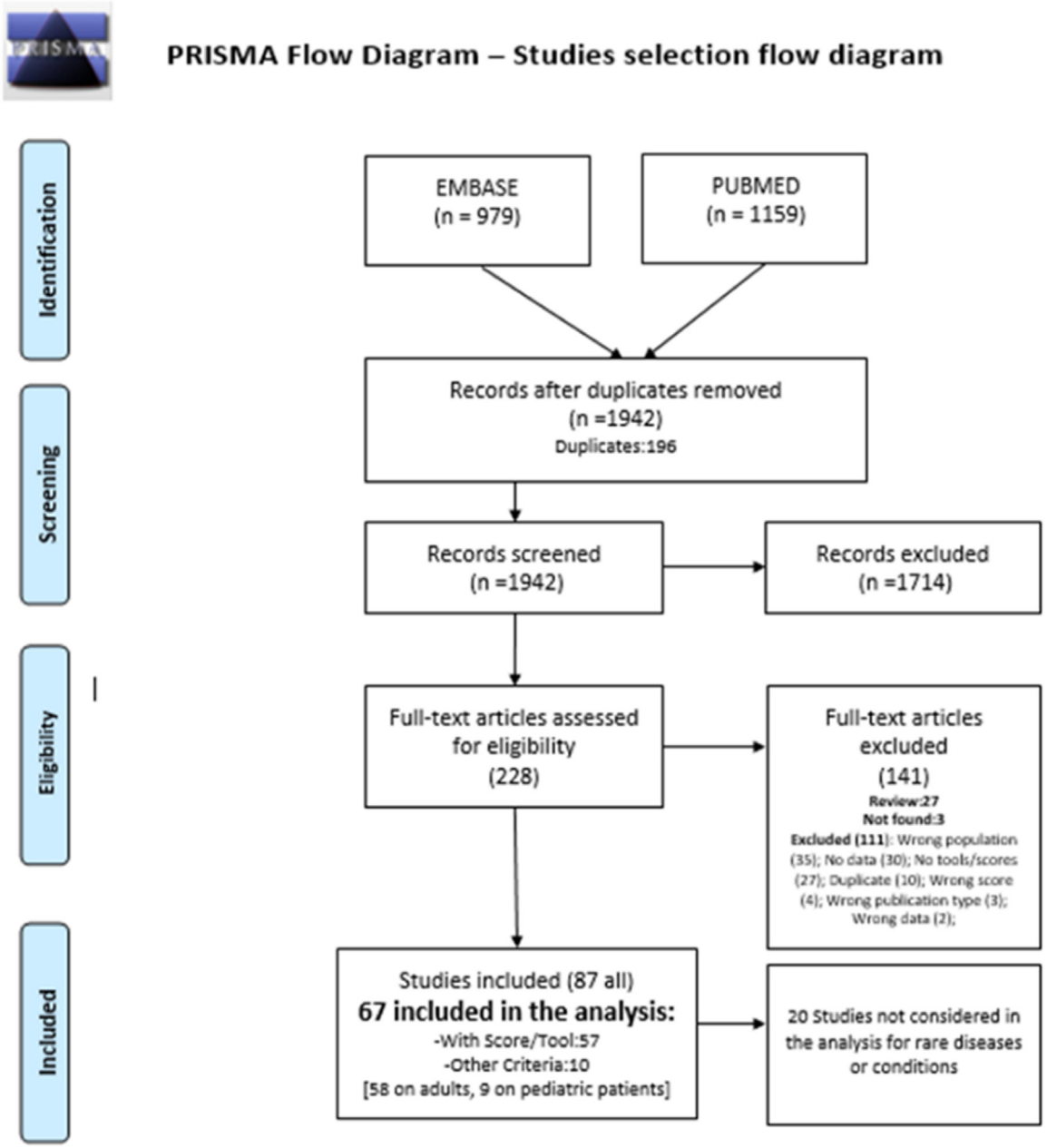

Figure 3. Studies selection flow diagram and main reasons of exclusion.

Table 1
Prevalence of malnutrition in adult populations

Populations	# Studies	Sample size	Heterogeneity	Mean Prevalence (95% CI)
Chronic pathologies	16	3100	High	46.6% (28.6 to 64.6)
General population	12	4927	High	39.8% (20.5 to 59.2)
Overall Hospital patients (M+S+O)	18*	9435	High	48.7% (39.3 to 58.1)
Hospital patients (Medicine)	14	4279	High	50.1% (36.8 to 63.4)
Hospital patients (Surgery)	6	1300	High	49.7% (29.3 to 70.2)
Hospital patients (Oncology)	2	2013	NA	49.6% (47.5 to 51.8)
Long-term care	15	7879	High	68.8% (58.0 to 79.5)

CI, confidence interval; M, Medicine; NA, Not applicable; O, Oncology; S, Surgery
*Total number of studies on the adult Hospitalized population is less than the sum of studies on its single elements (Medicine, Surgery and Oncology), as 3 studies report on mixed populations.

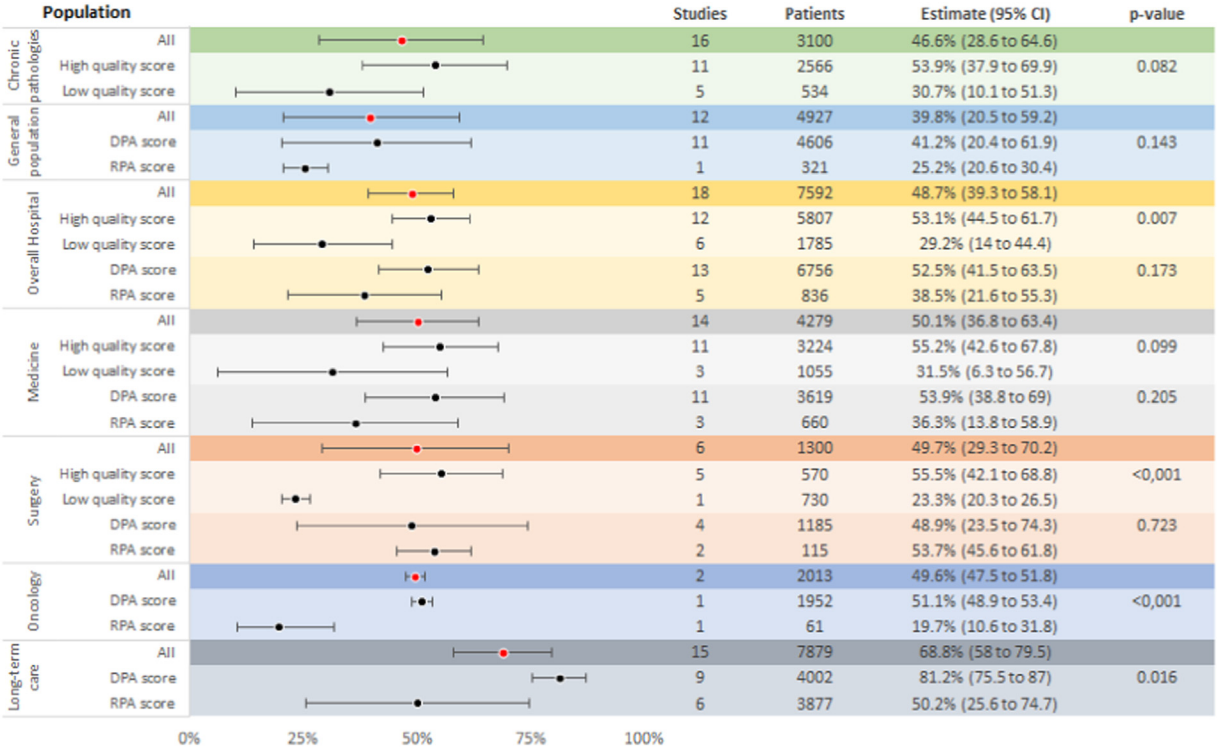

Figure 4. Subgroup analysis on study quality (high versus low) and type of assessment score (diagnosed prevalence analysis versus risk prevalence analysis).

participants in an appropriate way; most common limitations were inappropriate response rate and inappropriate sample size.

Pooled prevalence estimates: Adults

Table 1 reports the meta-analytical mean (95% CI) prevalence of malnutrition estimates for all considered adult populations and range from 40% (21–59%) in the general population to 69% (58–80%) in long-term care patients. High heterogeneity is detected in all groups (Supplementary Fig. 1–7).

When analyzed by subgroups, high-quality scores constantly yield higher prevalence estimates (Fig. 4); the same trend, although maybe less pronouncedly, was observed when comparing prevalence estimates based on diagnostic tools, as compared with both the general estimate and the risk for malnutrition assessment tools subgroup (Fig. 4)

Prevalence of malnutrition in the general adult population was reported in 12 studies (n = 4927), with a pooled mean prevalence of 40% (21–59%). All studies for this group assessed malnutrition according to methods in the HQA list, and therefore HQA and PA coincide. Prevalence based on risk assessment tools (RPA) was estimated at 25% (21–30%), whereas malnutrition diagnosis-based prevalence (DPA) was numerically higher, at 41% (20–62%).

Eighteen of the included studies (n = 7592) reported on prevalence of malnutrition for patients hospitalized in any ward, yielding a pooled mean of 49% (39–58%). Considering only the 12 HQA studies (n = 5807), mean prevalence was even higher, at 53% (45–62%). Mean prevalence from RPA in this patient group was 39% (22–55%), again lower than the DPA estimate, which was 53% (42–64%).

As anticipated, the higher prevalence pattern observed with HQA holds valid for all other patient groups analyzed: in medicine wards the estimate was 50% (37–63%) in the PA (14 studies, n = 4279; Supplementary Fig. 3) and 55% (43–68%) in the HQA (11 studies, n = 3224); 50% (29–70%) in PA (6 studies, n = 1300; Supplementary Fig. 4) and 56% (42–69%) in HQA (5 studies, n = 570) for surgical patients; prevalence of malnutrition in patients affected by chronic pathologies was also lower in PA (16 studies, n = 3100) than in HQA (11 studies, n = 2566): 47% (29–65%) versus

Table 2
Prevalence of malnutrition in pediatric populations

Populations	# Studies	Sample size	Heterogeneity	Mean Prevalence (95% CI)
Chronic pathologies	1	340	NA	30.9% (26.0 to 36.1)
General population	3	8664	High	8.5% (6.1 to 10.8)
Overall Hospital patients (M+S+O)	5	2767	High	25.1% (11.9 to 38.2)
Hospital patients (Medicine)	4	977	High	24.2% (6.4 to 42.0)
Hospital patients (Surgery)	0	0	NA	NA
Hospital patients (Oncology)	1	126	NA	100%

CI, confidence interval; M, Medicine; NA, Not applicable; O, Oncology; S, Surgery.

Table 3
Additional cost of DRM due to LOS increase, Hospital perspective

Subgroup	DRM prevalence (base case)	Cost (Million €) Base case	Cost (Million €) Raw scenario	Cost (Million €) Best scenario	Cost (Million €) Worst scenario €
Total Italy 2018		9,085	8,821	3,210	16,331
Adult, Oncologic	49.6%	632	598	262	1,066
Adult, Medical	55.2%	4,883	4,630	1,692	8,856
Adult, Surgical	55.5%	3,318	3,146	1,132	6,040
Pediatric (all)	25.1%	252	446	124	370

Table 4
Additional cost of DRM due to increased frequency of hospital admissions, NHS perspective

Scenario	Adult population		Pediatric population	
	Δ H admissions (Thousand)	Total cost (Million €)	Δ H admissions (Thousand)	Total cost (Million €)
Base case	1,206	3,372 €	125	327 €
Best	426	1,191 €	26	67 €
Worst	1,986	5,552 €	223	586 €

DRM, disease-related malnutrition; NHS, Italian National Health Service.

54% (38–70%). For oncology (2 studies, n = 2013), and long-term care patients (15 studies, n = 7879), PA and HQA coincided, with mean prevalence estimates of 50% (48–52%) and 69% (58–80%), respectively.

Similarly, RPA yielded lower estimates than DPA: In medicine wards the estimate was 54% (39–69%) in the DPA (11 studies, n = 3619) and 36% (14–59%) in the RPA (3 studies, n = 660); 51% (49–53%) in DPA (1 study, n = 1952) and 20% (11–32%) in RPA (1 study, n = 61) for oncology patients; the same pattern emerged in long-term care patients, with a significantly higher estimate at 81% (76–87%) in DPA (9 studies, n = 4002) than in RPA (50% [26–75%], 6 studies, n = 3877). Only for surgical patients was the prevalence estimated in the RPA (54% [46–62%], 2 studies, n = 115) higher than the DPA estimate (49% [24–74%], 4 studies, n = 1185).

Pooled prevalence estimates: Pediatric patients

Table 2 shows the estimates of the mean (95% CI) prevalence of malnutrition in pediatric populations. They range from 9% (6–11%) in the general population (3 studies, n = 8664; Supplementary Fig. 8) to 31% (26–36%) in children with chronic illnesses. For pediatric patients hospitalized in any ward (5 studies, n = 2767; Supplementary Fig. 9) prevalence was estimated at 25% (12– 38%), in the hospital medicine subgroup (4 studies, n = 977; Supplementary Fig. 10) prevalence was 24% (6–42%).

No meta-analysis could be performed for the chronic illness group, containing a single study [88], nor for oncology patients, where it must be noted that the reported 100% was inherent with the pathology, the assessment tool, and the cutoff for moderate risk for malnutrition adopted in the present analysis. No subgroup analyses could be conducted on the pediatric population due to data unavailability.

Cost of illness

Hospital perspective

Eleven observational studies comparing malnourished to non-malnourished admitted adults were identified by our critical literature review [13,64,71,93–100], and four studies reported the effects of DRM on LOS in children [15,101–103] (Supplementary Table 5). Malnutrition assessments in the considered studies was based on the same definitions adopted for the epidemiologic data, with low RoB studies using diagnostic tools compared with risk scores.

Base case scenario considered a 62% increase in mean LOS for adults (23–128% in alternative scenarios); 30% was the relative increase estimated for the pediatric population (30–57% for scenario analyses) (Supplementary Table 6). Considering these relative LOS increases on about 43 million yearly inpatient days (Supplementary Table 8), in our base case scenario we estimated that Italian hospital providers must annually front more than $10.6 billion attributable to DRM (Table 3). This estimate varies between about $3.18 and $17 billion per year in the explored scenarios.

NHS perspective

Incremental admission risk rate for DRM patients results in almost 2 and 4 for adult and pediatric patients, respectively (Supplementary Table 7), leading to estimated additional $3.5 billion yearly reimbursed by the NHS for extra hospitalizations attributable to DRM in the base case (from $1.3 to $6 billion in alternative scenarios; Table 4).

Discussion

To our knowledge, this was the first study to systematically address the prevalence of malnutrition across the age spectrum

and in different settings (hospital, community, long-term care) in Italy as well as its economic consequences for LOS increase both from the hospital and the NHS perspective.

Based on peer-reviewed literature published in over the past 15 y, we estimated that 40% of the Italian general adult population, and 9% of children and adolescents, are moderately to severely malnourished. These already impressive figures rise to about 50% and 30% in the hospitalized fraction of the same age groups, and up to 70% in the predominantly elderly long-term care population.

Compared with data from international studies, the present study confirms a very high prevalence of malnourished patients in all the settings considered. Regarding the general population, a recent study reported an estimated absolute rate of moderate and high nutritional risk of 35% and 29%, respectively [104], which, when taken together, exceed the 40% demonstrated in this study. On the other hand, lower prevalence has been reported by other authors [10,105]. Most of the studies addressing the issue of malnutrition in community-dwelling individuals have been conducted in the older age group, a population typically characterized by polymorbidity.

When studies considering patients with chronic conditions were selected, the prevalence of malnutrition rose to 47% and 54% in the high-quality subgroup. When considering the hospital setting, these figures further increased, as expected. However, very little deviations were noted when comparing the different settings (medicine, surgery, and oncology); recently Marinho et al. reported a prevalence of malnutrition of 73% in patients acutely admitted to internal medicine [5] whereas in surgical patients with cancer, an overall prevalence of 60% has been described [106]. Findings from the present study are especially relevant considering that malnutrition prevalence increases during a hospital stay. Van Vliet et al. reported a malnutrition prevalence of 31% at hospital admission, which increased to 36% before discharge [107]. Additionally, because the mean age of hospitalized adults is progressively increasing, malnutrition often overlaps with sarcopenia and frailty, which concomitantly contribute to poor clinical outcomes [108]. Similar results have been reported for community-dwelling older adults [109]. For residents of nursing homes and long-term care facilities, the finding of a malnutrition prevalence of 69% is in line with the reported prevalence in other studies [12,110].

An interesting, albeit not completely new, finding is that prevalence estimates based on risk assessments are 10% to 30% lower than actual diagnosis-based estimates in all analyzed patient groups except surgery patients. This data, in agreement with Velasco et al. [111], raises concerns about the adequacy of current malnutrition risk screening tools that demonstrate low sensitivity and may need to be more clinically useful as diagnostic criteria. Data on the pediatric population is especially relevant. The present study demonstrated that in Italy, 31% of children with chronic conditions and 25% of those in the hospital are affected by malnutrition. Considering the consequences of malnutrition not only for patient health and development but also for society, once diagnosed, its treatment is mandatory. As an example, malnourished children acquire nosocomial infections more often and have significantly increased hospital LOS [16] compared with those who are not malnourished. In a large prospective multicenter European study reduced BMI <-2 SDS was also associated with increased prevalence of diarrhea, vomiting, and a lower quality of life [15].

In adults, malnutrition even in the moderate stage has severe consequences on health-related outcomes. Notably, in the presence of poor nutritional status, morbidity and complication rates, mortality, hospital LOS, need for multidisciplinary interventions, and treatment costs increase significantly [5,112,113], with worse nutritional conditions showing a more significant effect on adverse clinical outcomes [3,94,114].

When regarded from an economic point of view, our analysis estimates nearly $12 billion in yearly excess cost for Italian health care providers attributable to DRM-induced LOS increase, and an additional extra $5.3 billion in annual DRG reimbursements by the NHS. These estimates cannot be summed for methodological issues. Still, because the NHS mainly funds health care providers in the Italian health care system, some excess costs on providers will spill over. The magnitude of the cost of illness estimates for Italy compares well with findings of previous studies: >$15 billion, $10 billion, and $2 billion annual costs of DRM were estimated for the United States, Latin American countries, and Canada, respectively. Studies from Europe report that DRM in hospitalized children is associated with an increase in annual hospital costs with an additional yearly amount of $85 million [103]. The cost of adult undernutrition was estimated at $8.8 billion annually in the United Kingdom [115].

Conclusions

Likely, the already impressive economic effects of DRM presented in this study are an underestimation, as we only considered the effect of LOS prolongation and higher admission rates while neglecting other known drivers of cost increases, such as higher cost of infection management and more significant resource consumption in long-term care, let alone the indirect cost effects on productivity losses for the society. Another source of possible underestimation of the actual effects could be related to the choice of using overall estimates, which are substantially lower than actual diagnosis-based prevalence estimates, as discussed above.

The effects on health care systems, however, is not an inevitable fact of life: diagnosis and treatment of malnutrition have been demonstrated crucial in the management of patients in very different settings to jointly improve clinical outcomes and to reduce health care expenses. Treatment of malnutrition results in health care savings and in improved outcomes both in the community and in hospital settings, including fewer complications, shorter hospital stays, better quality of life and reduced 30-d mortality rate [13,116]. These findings were demonstrated both for the adult and pediatric populations [117,118].

We strongly recommend that these considerations be interpreted in a call for action for increased awareness of the diffusion and effects of DRM among all health care settings and players, both in clinical and decision-making roles, and for a greater empowerment of clinical nutrition services, that should be considered as strong value-drivers of the Italian health service.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2022.111943.

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