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ORIGINAL ARTICLE

An in-depth assessment of diabetes-related lower extremity amputation rates 2000–2013 delivered by twenty-one countries for the data collection 2015 of the Organization for Economic Cooperation and Development (OECD)

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Abstract

Background International comparisons of diabetes-related lower extremity amputation rates are still hampered by different criteria used for data collection and analysis. We aimed to evaluate trends and variation of major/minor amputations, using agreed definitions adopted by the Organization for Economic Cooperation and Development in 2015.

Methods Direct age–sex standardized rates were calculated per 100,000 subjects per year between 2000 and 2013, using major/minor amputations with diabetes diagnosis as numerators and the total population or number of people with diabetes as denominators. Longitudinal trends were investigated using generalized estimating equations.

Results Twenty-one countries reported major amputations referred to the general population, showing a mean reduction from 10.8 to 7.5 per 100,000 (−30.6%). Eleven countries also reported major amputations among people with diabetes, showing a mean reduction from 182.9 to 128.3 per 100,000 (−29.8%). Minor amputations remained stable over the study period. Longitudinal trends showed a significant average annual decrease of −0.19 per 100,000 in the general population (95% CI −0.36 to −0.02; $p=.03$) and −4.52 per 100,000 among subjects with diabetes (95% CI −6.09 to −2.94; $p<.001$). The coefficient of variation of major amputation rates between countries was fairly high (64%—in the total population, 67% among people with diabetes).

Conclusions The study highlighted a clinically significant reduction of major amputations, in both the general population and among people with diabetes. The use of standardized definitions, while increasing the comparability of multinational data, highlighted remarkable differences between countries. These results can help identifying and sharing best practices effectively on a global scale.

Keywords Lower extremity amputations in diabetes · Healthcare Quality Indicators · Diabetes care · Health systems performance assessment · Generalized estimating equations

Managed By Massimo Porta.

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Introduction

The effectiveness of healthcare interventions should be routinely monitored using indicators that can be practically used to improve performance [1].

Lower extremity amputations represent a major threat for people with diabetes, due to the associated burden and increased risk of a fatal outcome [2]. Preventive strategies include targeted interventions to reduce the odds of amputations through better metabolic control and systematic foot care at an early stage of the disease [3].

Targeted indicators can provide meaningful clinical advise on how diabetes care aligns with expected targets, e.g. major and minor amputations [4]. These can occur for different reasons (the minor to salvage the limb, the major to save the patient) and should be interpreted accordingly.

The Organization for Economic Cooperation and Development (OECD) has been collecting lower extremity amputation rates in diabetes (LEARD) from national governments since 2006 [5, 6]. Every 2 years, the OECD requests participating countries the entire time series from 2000 onward, using a well-specified protocol that is revised over time based on activity on field. Data gathered include the number of amputations and total population per year by sex and age bands.

So far, the number of countries adopting LEARD for national reporting appears to be substantially lower compared to other performance indicators [7]. A potential explanation can be found in the critical limitations highlighted for the OECD data collection 2013 [4].

According to the definitions therein applied, duplications were possible as repeated counts of amputations in the same subject were all included in the numerator. This reflected the fact that in many countries, following individuals over time is not feasible, due to the unavailability of a unique personal identifier (UPI) or the restrictions imposed by data protection regulations [8, 9].

Moreover, there was no clear indication on the use of registries and poor coverage of non-ICD9 coding. Finally and most importantly, the clinical rationale was weak, as the exclusion criteria were too limited and minor and major lower extremity amputations were not differentiated.

To improve the reporting of LEARD, an international group of experts agreed to revise and use new definitions for the OECD data collection 2015.

In this paper, we use the resulting database to respond to the following research questions:

- How do countries compare in terms of major and minor LEARD?
- What are the long terms trends highlighted by the new time series 2000–2013?
- Which are the main country-level factors affecting the heterogeneity of results?

The following sections report the main findings of our investigation.

Materials and methods

The analysis was conducted using materials produced in various preparatory steps of the OECD data collection 2015, summarized in the following subsections.

Background materials and revised standardized definitions of LEARD

Revised standardized definitions of LEARD for 2015 were produced by national representatives of the OECD expert group of Healthcare Quality Indicators (HCQI), coordinated by the Italian Ministry of Health in collaboration with the Italian National Agency for Regional Health Services (AGENAS) and the EUBIROD network of diabetes registers (http://www.eubirod.eu).

An exploratory survey of data sources and algorithms for the calculation of LEARD was conducted by volunteering governmental organizations of Ireland, Israel, Italy, Latvia, Norway and Slovenia between July–September 2014. Responses covered aspects of data linkage, standardized definitions, reporting, availability of a UPI and presence of diabetes registers.

A set of twenty reports were collected to provide a background on the topic, of which nineteen were extracted from PubMed/Google Scholar using "lower", "amputation", "diabetes" and "indicator" as search keywords over the timeframe 2009–2014, plus the operating manual used for the OECD data collection 2013.

A draft set of definitions prepared in consultation with partners of the EUBIROD network was tested on the Italian National Database of hospital discharges, 2002–2013.

All results were collected in a final report [10] that was distributed as background material at the second annual HCQI meeting 2014. The proposed criteria were presented by the OECD Secretariat to the Expert Group, which voted for their adoption in the data collection 2015 (see Table 1) [11].

Data collection process

Standardized definitions were provided to designated governmental organizations involved with the OECD data collection 2015, which processed national databases using their own internal resources and local facilities. The OECD secretariat sent an empty formatted Excel sheet to representatives of 36 Member States and associated countries involved in the HCQI project [11], to be returned duly filled between January and May 2015. Countries were requested to specify the total number of subjects per numerator and denominator by sex and age bands for all years between 2000 and 2013.

Additional contextual data (see Table 2) were added to explore the association of LEARD with fundamental health systems characteristics (funding mechanism) and data collection procedures (use of a registry to collect amputations, ICD-9 derived coding).

Table 1 Standardized definitions applied for the OECD data collection of amputation rates 2015

Numerator	Total number of subjects according to the specific calculation method (see below) *Inclusion criteria*: The numerator includes the number of cases: of all non-maternal/non-neonatal admissions **presenting a procedure code of major lower extremity amputation in any field** (ICD-9-CM: 8413 "disarticulation of ankle", 8414 "amputation through malleoli", 8415 "below knee amputation", 8416 "disarticulation of knee", 8417 "above knee amputation", 8418 "disarticulation of hip", 8419 "hindquarter amputation"; ICD-10-WHO: not specified) **and a diagnosis code of diabetes in any field in a specified year** (ICD-9-CM: 25000–25003, 25010–25013, 25020–25023, 25030–25033, 25040–25043, 25050–25053, 25060–25063, 25070–25073, 25080–25083, 25090–25093; ICD-10-WHO: E10.0–E10.9, E11.0–E11.9, E13.0–E14.9) In addition, countries were also requested to separately provide the number of cases: **presenting a procedure code of minor lower extremity amputation** (ICD-9-CM: 8411: "toe amputation", 8412: "amputation through foot"; ICD-10-WHO: not specified) **and a diagnosis code of diabetes in any field in a specified year** (same as above). *Exclusion criteria*. Cases were excluded from numerator if records include either: transfer from another acute care institution MDC 14 or specified pregnancy, childbirth, and puerperium codes in any field MDC 15 or specified newborn and other neonates codes in any field trauma diagnosis code in any field (ICD-9-CM: 8950 "toe amputation", 8951 "toe amputation complicated", 8960 "amputation foot unilateral", 8961 "amputation foot unilateral complicated", 8962 "amputation foot bilateral", 8963 "amputation foot bilateral complicated", 8970 "amputation below knee unilateral", 8971 "amputation below knee unilateral complicated", 8972 "amputation above knee unilateral", 8973 "amputation above knee unilateral complicated", 8974 "amputation leg unilateral not specified", 8975 "amputation leg unilateral not specified complicated", 8976 "amputation leg bilateral", 8977 "amputation leg bilateral complicated"; ICD-10-WHO: S78.0 "traumatic amputation at hip joint", S78.1 "traumatic amputation at level between hip and knee", S78.9 "traumatic amputation of hip and thigh, level unspecified", S88.0 "traumatic amputation at knee level", S88.1 "traumatic amputation at level between knee and ankle", S88.9 "traumatic amputation of lower leg, level unspecified", S98.0 "traumatic amputation of foot at ankle level", S98.1 "traumatic amputation of one toe", S98.2 "traumatic amputation of two or more toes", S98.3 "traumatic amputation of other parts of foot", S98.4 "traumatic amputation of foot, level unspecified", T05.3 "traumatic amputation of both feet", T05.4 "traumatic amputation of one foot and other leg (any level, except foot)", T05.5 "traumatic amputation of both legs (any level)", T13.6 "traumatic amputation of lower limb, level unspecified") tumour-related peripheral amputation code in any field (ICD-9-CM: 1707 "Malignant neoplasm of long bones of lower limb", 1708 "Malignant neoplasm of short bones of lower limb"; ICD-10-WHO: C40.2 "Malignant neoplasm of long bones of lower limb", C40.3 "Malignant neoplasm of short bones of lower limb") same day/day only admissions
Denominator	Countries were asked to report two different types of denominators: **Total population**: simple count of number of subjects from the general population by age (0–14, 15–34, 35–44, 45–54, 55–59, 60–64, 65–74, 75+) and sex (males, females); **Total number of people with diabetes** calculated using estimates of diabetes prevalence reported as percentages of the total population by age and sex stratum. Countries with different intervals ranges may apply estimates, e.g. the average or a linear estimate across the cohorts
Calculation method	*Admission-based method*. Numerator captures **all hospital admissions satisfying the inclusion/exclusion criteria in the specified year** *Patient-based method*. Numerator only captures the admission with the **most severe amputation** for each diabetic patient admitted for an amputation in the specified year. The diabetic patients are identified through the use of unique person identifier (UPI). For all patients with an amputation in the specified year, countries were asked to search for diabetes diagnoses retrospectively (up to a maximum of 5 years, including the reference and prior years). Possibly, the search should extend via data linkage from hospital datasets to other relevant databases (e.g. pharmaceutical, specialist, laboratory data)

Statistical analysis

The authors of the present paper were given direct access to all Excel worksheets returned to the OECD, soon after the publication of Health at a Glance 2015 [11].

Different indicators were calculated using the data available, based upon the different definitions of numerators (number of major and minor amputations) and denominators (total population and people with diabetes). The impact of multiple amputations over the same subject was evaluated through "patient-based estimates", calculated using the most severe amputation observed in each year for the same subject (see Table 1). Although figures were available for all age–sex classes, LEARD

Table 2 OECD countries reporting data for this study and their health system characteristics

OECD country	T	R	C
Australia (AUS)	Y	N	2
Belgium (BEL)	N	N	1
Canada (CAN)	Y	N	2
Denmark (DNK)	Y	Y	2
France (FRA)	N	N	3
Germany (DEU)	N	N	2
Iceland (ISL)	Y	Y	3
Ireland (IRL)	Y	N	2
Israel (ISR)	N	N	1
Italy (ITA)	Y	N	1
Korea (KOR)	N	N	3
Luxembourg (LUX)	N	N	3
Netherlands (NLD)	N	Y	3
New Zealand (NZL)	Y	N	2
Norway (NOR)	Y	Y	3
Portugal (PRT)	Y	N	1
Slovenia (SVN)	N	N	2
Spain (ESP)	Y	N	1
Sweden (SWE)	Y	Y	3
Switzerland (CHE)	N	Y	1
UK (GBR)	Y	N	3

Coding: T: funding mechanism = tax-based (Y/N); R: source = registry (Y/N); C: coding = ICD9 derived (1), ICD10 derived (2), or Other (3). Source: OECD Health System Characteristics Survey 2012

were calculated only for subjects aged 15 or over, due to the very low number of events recorded at early ages.

Statistical analysis included the calculation of crude and direct age–sex standardized rates per 100,000 subjects for all definitions, by country and year. The pooled population from all participating countries at year 2013 or last year available was used as the standard.

Descriptive measures were used to respond to the first research question regarding the most current international comparisons of LEARD, including: measures of centrality (mean, median, range) and dispersion (coefficient of variation × 100, CV).

Graphical outputs included histograms of amputation rates by country and boxplots superimposed to turnip charts to display results over time [12]. In both cases, an average line representing the OECD arithmetic mean value of data points for each year is added to the graph.

All data points used for graphical outputs refer to the value recorded each year or for the last year available.

Multivariate modelling

Linear and Poisson multivariate models using Generalized Estimating Equations (GEE) were carried out to address the second and third research questions.

The GEE models were used to ensure robust confidence intervals for correlated values within countries (exchangeable structure) [13]. This method allowed deriving estimates of annual changes based on the entire time series, thus not excluding countries presenting any missing values for specific years in the timeframe.

Linear models allowed estimating the average annual change in LEARD, taking into account the main country-level characteristics that might have influenced the data collection process. Poisson models were applied to estimate the average increase/decrease in incidence of LEARD due to country-level factors (public vs. private financing, data derived from diabetes registry, ICD vs. non-ICD coding classification), independently from average annual change over time and composition of the population by age and sex.

Results of multivariate models were expressed as point estimates and 95% confidence intervals. For linear models, estimates reported changes in amputation rates per 100,000 subjects, per unit increase of each covariate (upper vs. lower class of age; named category vs. complementary, e.g. males vs. females). For Poisson models, estimates were reported as incidence rate ratios (IRR), i.e. increased/decreased incidence per unit increase of each covariate (as above).

Sensitivity analysis was carried out to test relevant changes in parameter estimates of regression models: a) by excluding selected covariates; and b) by comparing results obtained splitting the sample of observations in two separate time frames: up to year 2007 and 2007–2013.

All analyses were performed using the R statistical language [14].

Results

Response rates and data coverage

A total of 21 (58%) countries delivered data for the study.

The timeframe was not evenly covered, with most countries reporting from 2007 on. The last year available was 2013 for 15 (42%) countries, 2012 for New Zealand, Switzerland and Luxembourg (8%) and 2011 for Belgium and The Netherlands (6%).

All participants delivered data on major amputations and total population at least for 1 year, by sex and age bands. Among them, 16 (44%) countries reported also minor amputations.

A subset of 11 (31%) countries delivered the total number of people with diabetes by sex and age bands, allowing the calculation of crude overall diabetes prevalence rates for 2013 or last year available (median: 7.2, range: 5.7–9.4) and the indicator using people with diabetes in the denominator.

Age–sex standardized rates for all definitions and the entire timeframe are included in Tables A1 and A2 in the Appendix (supplementary data).

International comparisons for last year available

Results obtained for year 2013 (or last year available) are displayed in Fig. 1.

The mean value (range) of major amputations was equal to 7.5 per 100,000 (1.2–17.6) and 128.3 per 100,000 (27.9–282.7) when referred to the total population and people with diabetes, respectively. The mean age–sex standardized rate of minor amputations was equal to 11.1 per 100,000 (1.2–32.1) in the total population and 184.3 per 100,000 (22.1–422.6) among people with diabetes, respectively.

In general, higher LEARD for all indicators were noted for Israel, Germany and Slovenia. On the other hand, Sweden, Italy, Korea and Luxembourg showed systematically lower LEARD.

The coefficient of variation between countries seemed fairly high (ranging between 64 and 67% for major and 82–87% for minor amputations in the total population and among people with diabetes, respectively).

Longitudinal trends

Longitudinal trends over 2000–2013 are shown in Fig. 2.

Overall, major amputations appeared to be decreasing over time, with the exception of 2008 and 2013. Trends were generally consistent across countries, with stronger declines (> 25%) observed for Israel, Italy, Luxembourg, New Zealand and Sweden. Minor amputations appeared generally stable until 2008; then, they started to increase. Trends are clearer when using people with diabetes in the denominator.

Impact of re-amputations

According to data delivered by seven countries (see Fig. 3), age–sex standardized rates of major amputations showed to be 17.5% higher on average than patient-based estimates, meaning that an equivalent portion can be attributed to re-amputations. The difference appeared to be higher for Sweden (+ 74%) and Italy (+ 32%), with all others falling below 9%.

The decreasing trend of LEARD was more clearly defined when using the patient-based method.

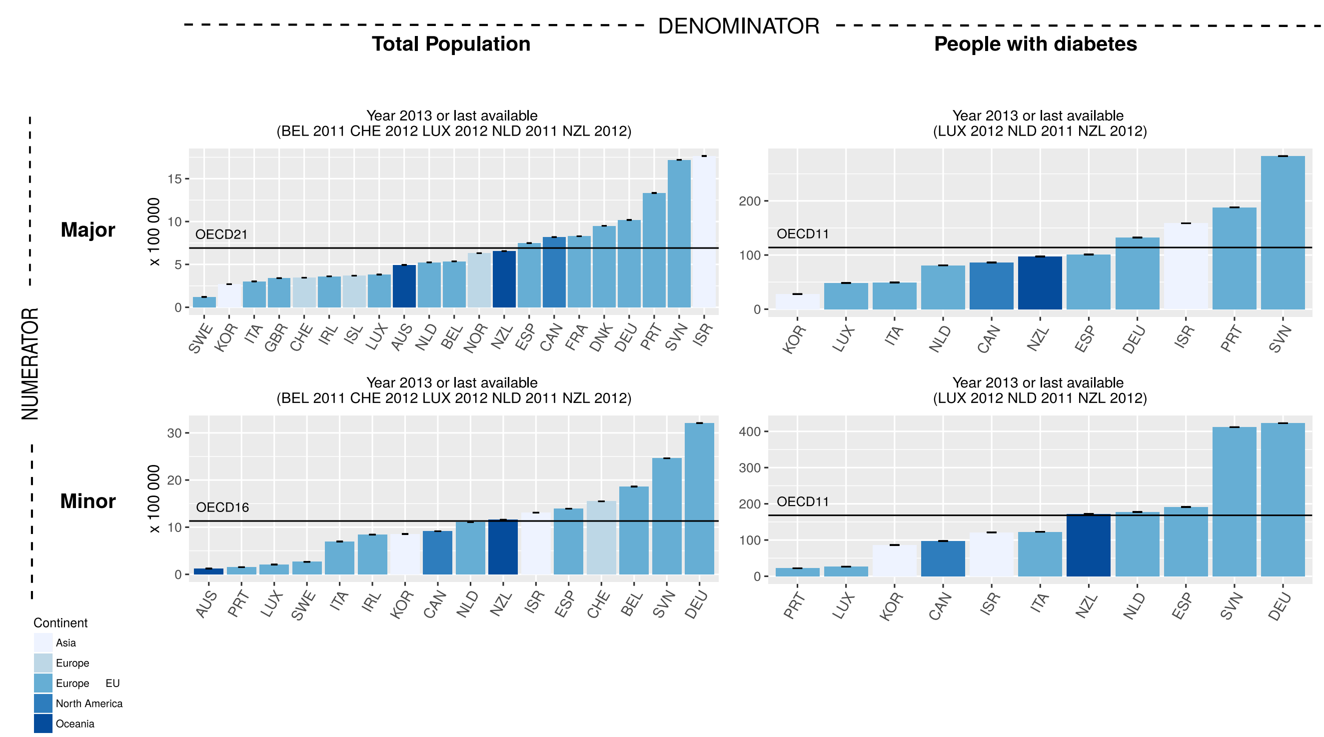

Fig. 1 Lower extremity amputation rates in diabetes according to different definitions, year 2013 or last year available, OECD data collection 2015

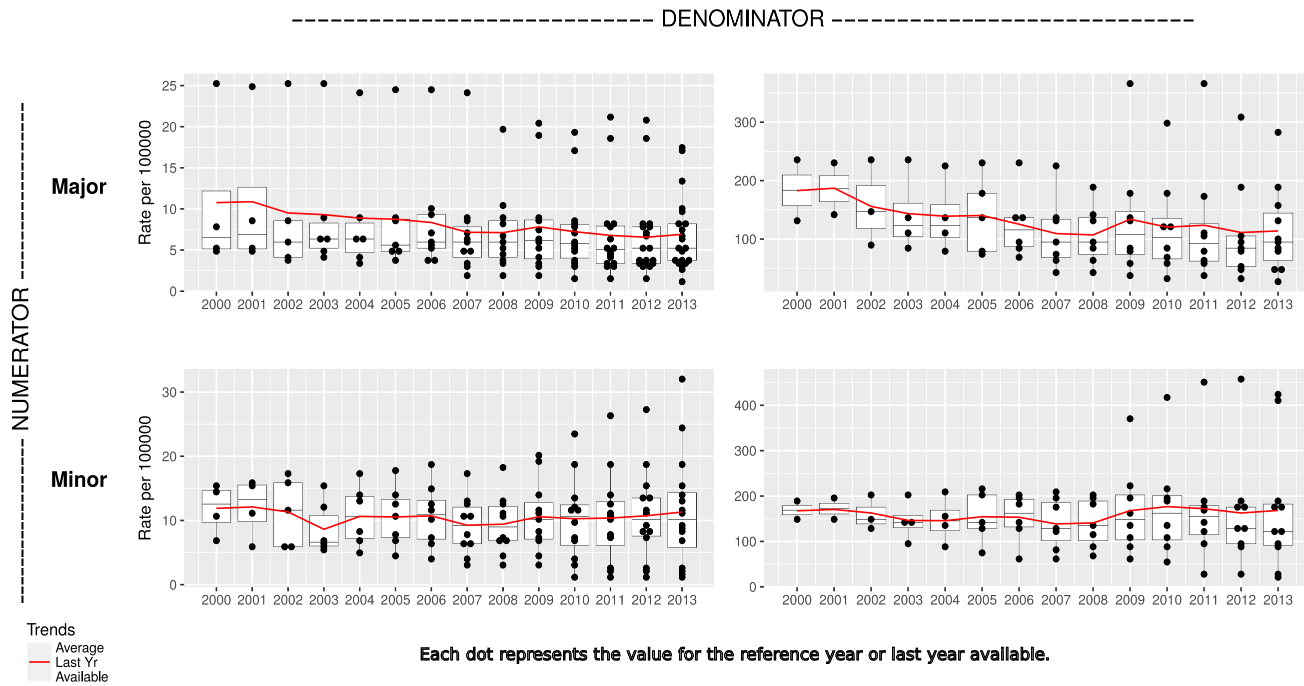

Fig. 2 Trends of lower extremity amputation rates in diabetes according to different definitions, year 2000–2013, OECD data collection 2015

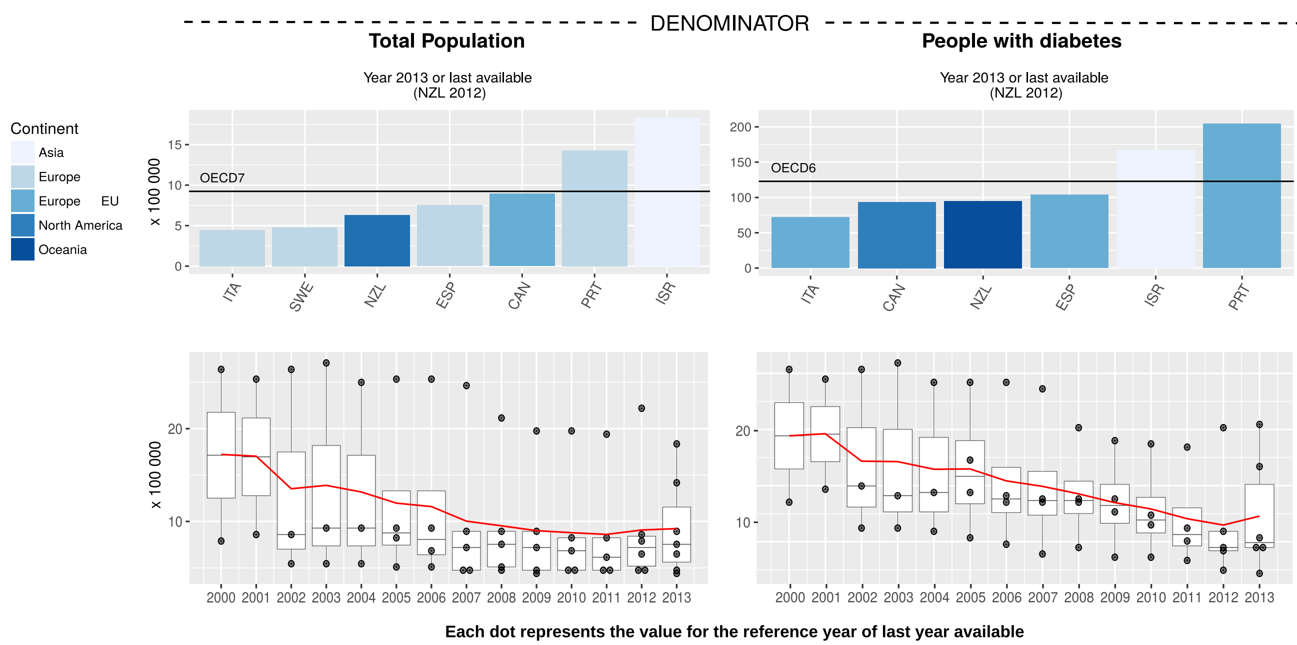

Fig. 3 Lower extremity major amputation rates in diabetes according to the patient-based estimate, OECD data collection 2015

Multivariate analysis

The results of GEE multivariate regression are included in Table 3.

Linear models (upper section, Model 1) confirmed a significant annual reduction of major amputations in the total population (– 0.19 per 100,000; 95% CI – 0.36 to – 0.02 per 100,000) as well as among people with diabetes

Table 3 Results of multivariate modelling of lower extremity amputations in diabetes (generalized estimating equations), OECD 2000–2013

Variable	Minor				Major			
	People with diabetes		Total population		People with diabetes		Total population	
Linear regression[a]								
	Estimate (95% CI)	$P>Z$	Estimate (95% CI)	$P>Z$	Estimate (95% CI)	$P>Z$	Estimate (95% CI)	$P>Z$
Model 1 (All)[b]								
Average year change	− 1.96 (− 4.02, 0.11)	0.06	0.12 (− 0.07, 0.31)	0.23	**− 4.52 (− 6.09,− 2.94)**	< 0.001	**− 0.19 (− 0.36, − 0.02)**	0.03
Model 2 (Tax-based)								
Average year change	− 1.09 (− 2.63, 0.46)	0.17	**0.17 (0.08, 0.26)**	< 0.001	**− 3.56 (− 5.08, − 2.05)**	< 0.001	**− 0.09 (− 0.13, − 0.05)**	< 0.001
Model 3 (Insurance-based)								
Average year change	− 1.88 (− 4.43, 0.67)	0.15	0.13 (− 0.18, 0.44)	0.41	**− 5.43 (− 6.87, − 3.99)**	< 0.001	− 0.25 (− 0.51, 0.01)	0.06
Poisson regression[c]								
	IRR (95% CI)	$P>\chi^2$	IRR (95% CI)	$P>\chi^2$	IRR (95% CI)	$P>\chi^2$	IRR (95% CI)	$P>\chi^2$
Model 4 (All)								
Age	**1.20 (1.06, 1.35)**	< 0.01	**1.87 (1.81, 1.94)**	< 0.001	**1.46 (1.36, 1.56)**	< 0.001	**2.05 (1.94, 2.16)**	< 0.001
Males	**3.05 (2.71, 3.43)**	< 0.001	**3.51 (3.03, 4.07)**	< 0.001	**2.20 (2.06, 2.35)**	< 0.001	**2.48 (2.23, 2.76)**	< 0.001
Insurance-based	**2.42 (1.08, 5.45)**	0.03	**2.99 (1.69, 5.28)**	< 0.001	**2.03 (1.17, 3.54)**	0.01	**1.86 (1.05, 3.28)**	0.03
Registry	**2.36 (2.00, 2.78)**	< 0.001	1.07 (0.75, 1.52)	0.70	**2.12 (1.94, 2.32)**	< 0.001	0.92 (0.57, 1.50)	0.75
Coding: non-ICD9/derived	**0.20 (0.11, 0.36)**	< 0.001	**0.36 (0.25, 0.53)**	< 0.001	**0.17 (0.15, 0.20)**	< 0.001	**0.51 (0.31, 0.85)**	0.01
Average year change	1.00 (0.98, 1.02)	0.810	**1.02 (1.01, 1.04)**	0.01	**0.96 (0.95, 0.98)**	< 0.001	**0.99 (0.97, 1.00)**	0.03

Statistically significant results ($P < .05$) are presented in bold

Source: OECD Health System Characteristics Survey 2012, Healthcare Quality Indicators 2015

IRR incidence rate ratio

[a]Outcome: age–sex standardized rates

[b]Covariates: financing, registry, coding (coefficients not shown)

[c]Outcome: number of lower amputations

(− 4.52 per 100,000; − 6.09 to − 2.94 per 100,000). Minor amputations did not change significantly in either case.

Separate analyses by financing mechanism showed variable results.

Systems with tax-based financing (Model 2) slightly increased their rates of minor amputations in the total population over time (0.17 per 100,000; 0.08–0.26 per 100,000), while major amputations in the total population (− 0.09 per 100,000; − 0.13 to − 0.05 per 100,000) and among people with diabetes (− 3.56 per 100,000; − 5.08 to − 2.05 per 100,000) decreased.

Systems with insurance-based financing (Model 3) reduced the rates of major amputations among people with diabetes (− 5.43 per 100,000, − 6.87 to − 3.99 per 100,000).

Poisson models (lower section) showed a significant 4% annual reduction in the incidence of major amputations among people with diabetes (IRR = 0.96, 0.95–0.98) and a 1% reduction for the total population (IRR = 0.99; 0.97–1.00). The incidence of minor amputations increased by 2% in the total population only (IRR = 1.02; 1.01–1.04).

Increased incidence of major amputations (among people with diabetes; total population) was significantly associated with age progression (IRR = 1.46, 1.36–1.56; 2.05, 1.94–2.16), being male (IRR = 2.20, 2.06–2.35; 2.48, 2.23–2.76), having an insurance-based financing mechanism (IRR = 2.03, 1.17–3.54; 1.86, 1.05–3.28) and using a diabetes registry as data source (IRR = 2.12, 1.94–2.32; 0.92, 0.57–1.50 NS). On the other hand, non-ICD9 coding systems had a significant lower chance of capturing cases both in the total population and among people with diabetes (IRR = 0.17, 0.15–0.20; 0.51, 0.31–0.85). The incidence of minor amputations showed similar patterns, with an increased number of cases among males and insurance-based systems.

Sensitivity analyses did not show substantial changes. In fact, different combinations of selected covariates did not alter either the annual changes or incidence rate ratios, while longitudinal trends did not show different patterns of adjusted annual changes up to and after 2007.

Discussion

The OECD data collection 2015 gathered a unique database of lower extremity major and minor amputations in diabetes from 21 countries of different parts of the world. To the best of our knowledge, this is the first investigation presenting a coherent approach for the collection of LEARD internationally from official sources. A rapid search of articles published between 2014 and 2018 found only national studies, with the exception of one review referred to different time frames, data collection methods and national objectives [15].

In 2013 (or last year available), the average rates of major amputations due to diabetes were equal to 7.5 per 100,000 when referred to the total population and 128.3 per 100,000 when referred to people with diabetes.

In specific countries, age–sex standardized rates of major amputations among people with diabetes were substantially higher than average. Specific cases of concern are those of Germany (132.2 per 100,000), Israel (158.7 per 100,000), Portugal (188.1 per 100,000) and Slovenia (282.7 per 100,000). These four countries alone account for over one third ($N=10{,}801$) of all major amputations in the total sample. On the other hand, much lower rates were noted for Italy (49.4 per 100,000), Luxembourg (48.4 per 100,000) and Korea (27.8 per 100,000).

In 2013 (or last year available), the average rates of minor amputations due to diabetes were equal to 11.1 per 100,000 when referred to the total population and 184.3 per 100,000 when referred to people with diabetes. The cases of Slovenia (411.6 per 100,000) and Germany (422.6 per 100,000) are those outstanding in terms of minor amputations among people with diabetes.

Compared to previous reports [4], the use of distinct definitions for major and minor amputations increased the accuracy of the data reported. In particular, given that major amputations are performed in hospital settings where data registration is more accurate, the reported rates are not biased by the uncertain number of minor amputations, which are more easily carried out in outpatient settings where data recording can be less accurate.

Computing major amputation rates using people with diabetes in the denominator is also more appropriate than using the total population.

Firstly, because it allows a proper evaluation of amputation risk using the correct reference population.

Secondly, because it cannot be biased by an increased diabetes prevalence. In fact, any reduction in rates occurred when more people with diabetes are diagnosed would be obscured if referred to the general population.

Overall, we found that 21 OECD countries experienced a significant average annual decrease of major amputations over 14 years regardless of the method of calculation.

The result shows good progress overall, consistently with a recent review of national reports [15]. However, the pace of improvement does not seem to guarantee a sharp decline of major amputations long term.

Multivariate Poisson models showed that, after adjusting by age, sex and average annual change, the incidence of both major and minor amputations in countries with insurance-based payments is double compared to that of national health systems.

This result confirms the findings of our previous analysis [4] for which precise explanations are still missing.

Can this relate to a more uniform and complete coverage of people with diabetes or to specific service arrangements?

Italy is a case in point: can the positive results be attributed to health system characteristics (e.g. financing system, universal coverage and decentralization) or to the specific organization of care for diabetes (comprehensive care and multiprofessional/multidisciplinary teams for diabetic foot management, coordinated by a diabetologist across three different levels of intervention). How much can be explained by individual lifestyles and personal characteristics? These questions require more granular data on the provision of care to be investigated with the required level of detail.

The impact of diabetes registries and classification systems on data accuracy highlights the importance of strengthening the information infrastructure. Effective strategies to overcome limitations in data accuracy include the intensive use of national databases [16], targeted surveys, e.g. the UK National Diabetes Audit [17] or the US NHIS [18], claims for selected populations, e.g. US Medicare [19], pay for performance schemes, e.g. the UK Quality and Outcomes Framework [20], computerized linked registries, e.g. the Finnish linkage of exemptions with A10 codes for pharmaceutical drugs and hospital discharges [21] and, above all, population-based registries, e.g. the DARTS in Scotland [22] and the Swedish Diabetes National Quality Register [23].

Improved data systems will allow using more accurate definitions that can allow international comparisons based on sound methods, e.g. life course analysis [24] and amputation-free risk-adjusted survival analysis [25]. In this perspective, the routine calculation of patient-based estimates should be encouraged further, as it can help the evaluation of outcomes in terms of person-centred care. Our data show that only few countries were able to deliver LEARD using a UPI. The high variation of estimates of re-amputations seems to suggest that in most cases the national information infrastructure may be still inadequate to support person-based comparisons.

Following the data collection 2015, the new definitions were officially endorsed to produce "Health at a Glance" [11, 26], the flagship OECD publication that further encouraged building national surveillance systems for the production of more accurate indicators [27].

International collaborations, e.g. the EUBIROD network can help leverage standards [28, 29] and improve the comparability of LEARD across health systems. Automating the process of data collection using common tools can help improving statistical reporting to support continuous benchmarking of diabetes care in ways that are not currently available [30].

Finally, key limitations of our study are worth to be outlined.

Firstly, we could not check directly how data were processed in each country. Different interpretations of the operating manual and software procedures may have affected data collection. However, the OECD secretariat continuously checked for consistency and any update of data sheets was taken into account for the production of this paper.

Secondly, the criterion applied for diabetes diagnosis may have not been unique. While diagnosis at the time of amputation was based on criteria applied at each episode (or before, if diagnosis was recovered from previous records), prevalence rates were requested altogether to countries in 2015. Since prevalence was estimated locally (using periodic surveys, computerized records, etc.), we could not ascertain whether numerators and denominators used the same criterion in each year.

Thirdly, the analysis was mainly based on country-level factors, with the exception of age and sex classes. This makes results prone to the ecological fallacy, meaning that we could not control for imbalances in other individual risk factors that might have altered estimates.

Fourthly, the association found for financing systems can only be interpreted as a composite proxy of a mix of system level characteristics, whose individual contribution cannot be ascertained with the data currently available.

Finally, and most importantly, given the lack of relevant clinical characteristics available, risk-adjusted models could not assess the impact of patient case-mix on amputation rates, which obviously limit the epidemiological interpretation of the associations found.

Conclusions

The rates of major amputations in OECD countries significantly decreased over fourteen years.

The use of standardized definitions, while increasing the comparability of multinational data, also showed remarkable differences between countries.

The results of this study can help fostering the ability to monitor diabetes-related amputations through a continuous improvement of coding practices and the repeated application of analytical models.

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Author's contribution FC, LU, MMB and NSK conceived and designed this study. FC designed the statistical analysis and analysed the data. FC, LU, MMB and NSK interpreted the results. FC wrote the first draft of the manuscript. FC, LU, MMB and NSK contributed to the writing of the manuscript. FC, LU, MMB and NSK agreed with the results and conclusions of the manuscript. All authors have read and confirmed that they met ICMJE criteria for authorship. All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. FC is the guarantor. We attest that we have obtained appropriate permissions and paid any required fees for use of copyright protected materials.

Data and resource availability The datasets generated during and/or analysed during the current study are not publicly available as they are held by the OECD as an integral part of their statutory activity of international data collection. Any request for access should be directly submitted to the OECD Health Division.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

Human and animal rights This article does not contain any studies with human or animal subjects performed by the any of the authors.

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