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Different patterns in medicinal plant use along an elevational gradient in northern Peruvian Andes

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ABSTRACT

Ethnopharmacological relevance: Through the study of mestizo people that share a common culture in a large geographic region and where traditional knowledge (TK) is still poorly documented, we compared medicinal plant use in the northern Andes of Peru.

Aims of the study: (1) To compare patterns of the distribution of TK for a human group living between two ecoregions: high tropical montane forests vs. low tropical montane forests; (2) to understand the TK at the gender level; and (3) to analyse TK transmission over five generations.

Material and methods: The study was conducted in two ecoregions, four areas and 12 localities. We gathered information with 600 participants through semi-structured interviews. We worked with 3–7 expert informants per locality using the "walk in the woods" methodology for gathering ethnomedicinal information in the field. We annotated local vernacular names, medicinal indications, and collected the plants in their habitats. Then we interviewed the rest of the participants in their homes. To evaluate significant differences between highlands and lowlands, we use general mixed linear models test and its corresponding *post hoc* LSD Fisher test of multiple comparisons ($p < 0.05$) at ecoregion, gender and generation level.

Results: A total of 416 species belonging to 107 plant families and 13,898 use-reports were found in both ecoregions. Overall, significant differences indicated that people in the highlands had higher TK than people in the lowlands for most of the medicinal categories. Women showed higher knowledge on medicinal plants in all medicinal categories and areas in both ecoregions. However, transmission of TK showed different patterns between ecoregions. In the highlands, the TK increased from the youngest to the senior group (51–60 years), with a slight decreasing for those over 60 years, whereas in the lowlands the findings were less clear and generations with highest TK were divergent across localities.

Conclusion: TK on medicinal plants is still widely applied in the tropical montane forests of northern Peru. The localities with less prosperous socioeconomic development (highlands) were the areas with higher TK on medicinal plants. Women are mainly the depositories of the traditional medicine. The older generations maintain most of the TK in the highlands, whereas in the lowlands the TK is more widespread across generations. Future conservation programs on medicinal plants should understand who are the generations depositaries of the TK before dedicate any effort.

1. Introduction

The traditional medicine based on plants has been maintained through history, especially in remote rural areas and among ethnic minorities of modern society, as a necessity for people with few economic resources or inaccessible medical assistance (Macía et al., 2005; Heinrich et al., 2006; Leonti and Casu, 2013). Nowadays, there are clear evidences of the fading of traditional knowledge (TK in the following) indicating that the chain of oral transmission between generations is breaking (Reyes-García et al., 2013; Paniagua-Zambrana et al., 2016). In response, the World Health Organization has among its objectives for the 2014–2023 decade, the recovery of popular knowledge about medicinal plants as an alternative for primary health care, mainly in the poorest regions of developing countries (WHO, 2013).

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This is the case of Peru, with at least 3000 species of medicinal plants documented (Mostacero et al., 2011). In the last decade the number of studies on medicinal plants has significantly increased in the country, and specifically in the Andean region (e.g. De la Cruz et al., 2007; Bussmann and Glenn, 2010; Mathez-Stiefel et al., 2012; Gonzales et al., 2014), although the eastern flank of the northern Andes is still scarcely studied (Bussmann and Sharon, 2006; Schjellerup et al., 2009).

In the tropical montane forests of northern Peru are living mestizo communities under different environmental conditions and socio-economic factors, which determine their life habits and also the use of medicinal plants in their surroundings. Along more than 2000 m in elevation, people have a culture relatively common that shares common human ancestors integrated into the territory of the prehispanic culture (Monigatti et al., 2013).

Generally, gender and age are key factors which determine the distribution of TK (Lambaré et al., 2011; Sousa Júnior et al., 2013). Women are the main vehicle for transmitting this knowledge in rural societies because they usually assume the main responsibilities of child and elders care (McDade et al., 2007; Wayland and Walker, 2014) although men showed a greater TK in some cases (e.g. Albuquerque et al., 2011; Paniagua-Zambrana et al., 2014). On the other hand, elder people are commonly the depositaries of ethnobotanical wisdoms and customs due to their accumulation of knowledge over time (Upadhyay et al., 2010). However, this knowledge can be evenly distributed among several age groups, even showing higher records in younger age groups by vertical, horizontal or oblique TK transmission (Idolo et al., 2010; Almeida et al., 2015).

In this work we have three objectives: (i) to compare the use of medicinal plants for a human group with a similar culture and living between two ecoregions: high tropical montane forests vs. Low tropical montane forests. We hypothesize that people with less economic resources and possibilities of resource exploitation will have greater traditional knowledge, which corresponds to the communities living in the highlands (Vandebroek, 2010); (ii) to analyze the distribution of TK on medicinal plants and gender equality between the two ecoregions. We expect women have a greater TK than men, due to the division of labour, where women mainly dedicate to the family health care whereas men mainly carry out agricultural and livestock work, or work outside their localities (Pfeiffer and Butz, 2005; Sher et al., 2015); and (iii) to understand the TK transmission over generations: 18–30, 31–40, 41–50, 51–60, > 60 years old between ecoregions. We expect elders have a greater TK than youngers due to their progressive accumulation of knowledge along their lives (Koster et al., 2016).

2. Methods

2.1. Study area

The study was conducted in the tropical montane forests of the Amazonas Department, in the eastern slopes of the northern Andes in Peru (Fig. 1). We worked in two different ecoregions according to their elevation: high tropical montane forests located between 2500 and 3500 m and low tropical montane forests, situated between 1500 and 2500 m. Both ecoregions have a seasonal climate, with a wet season from November to May and a dry season from June to October. In the highlands the annual average temperature is 14 °C and annual average rainfall is 780 mm, whereas in the lowlands is 19 °C and 900 mm, respectively (SENAMHI , 2017).

We studied two different areas per ecoregion and three localities per area (Fig. 1). In the highlands, the areas were: (1) Luya province, in the upper basin of the Utcubamba river and localities of Longuita, María and Yomblón; and (2) Chachapoyas province, in the upper basin of the Imaza river and localities of Granada, Olleros and Quinjalca. This ecoregion is mainly characterized by shrub vegetation and grassland extensions in a steep topography. The state of conservation is better than in the lowlands, but commonly altered by livestock pastures and agricultural activities of limited area (Young and León, 1988; Encarnación and Zárate, 2010). In the lowlands, the studied areas were: (1) Rodríguez de Mendoza province, in the middle basin of the Leiva river and localities of Totora, Santa Rosa and Huambo; and (2) Bongará province, in the middle basin of the Utcubamba river and localities of Valera, Cuispes and San Carlos. The conservation status of this ecoregion is discontinuous, with small patches of well-preserved forest but most areas are occupied by agriculture and livestock pastures (Schjellerup et al., 2009).

The population of both highlands and lowlands is conformed by spanish speaking mestizos. There are healers in every locality in both ecoregions, but they do not devote themselves exclusively to this labour. People respect them and sometimes visit them, particularly in cases of cultural and ritual diseases. Common diseases are usually treated with plants within the family and mainly by the elder females. A health post exists in each locality, without laboratories and with a limited supply of medicines, but fulfill the basic needs of their inhabitants. When more serious health problems happened, they need to go to Chachapoyas's city, where a hospital exists. The limitation arises among the inhabitants with less economic resources, mainly from the localities of Chachapoyas and Luya provinces, which not always are able to move in time to the hospital. The road conditions are highly variable along the year, but it usually takes 3–5 h.

The principal source of income in the highlands is obtained from beef cattle work and complemented with small scale vegetable crops, such as corn, beans and potatoes. They have difficult access to suitable infrastructures and limited access to basic health services, like drinking water supply. The population of the lowlands is mainly dedicated to coffee, corn and sugar cane cultivations, which sometimes is complemented with a diverse livestock of cows, pigs and sheeps. They have the facility to fish in rivers and lakes and commercialize their products. Overall, they have better infrastructure with nearby health services or hospitals, water treatments plants, and more prosperous economic conditions than population in the highlands. The population living in the six localities of the highlands is estimated at 3025 inhabitants, whereas in the six localities of the lowlands at 5865 inhabitants (INEI, 2015).

2.2. Data collection

To gather information about the uses of medicinal plants by local people, we carried out 50 semistructured interviews in each of the 12 localities of the Peruvian montane forests, totalling 600 interviews from July 2016 to May 2017. In the localities, we interviewed two types of informants: experts and generalists. The expert informants were those who have a greater knowledge of medicinal plants in their ecoregion and were chosen by the leaders of the respective localities. We interviewed 3–7 expert informants per locality, totalling 77. Experts were mostly women (62%) and older than 40 years (92%). With these informants, we used the “walk in the woods” methodology for gathering ethnomedicinal information in the field dedicating between 1 and 3 days with each person. We annotated local vernacular names, medicinal indications, and collected the plants in their habitats. For some species collected in sterile conditions and that could not be identified to species level, we carried out a second field trip to try to find them fertile.

Once the work with the expert informants was completed in a given locality, we listed all the medicinal plants, popular names, and diseases mentioned by these participants. Doing so, we have a full picture of the plant diversity and medicinal uses of the locality. Later, we worked with the general informants in their homes, interviewing one member of the different families (houses) in the locality, to gather as much distinct information as possible and to cover a larger portion of the local population. Using the list, we can be sure of the identification of the species during the interviews with the general participants. Within each locality, we seek for a balance in terms of gender and age. Informants were divided into five age groups: 18–30, 31–40, 41–50, 51–60

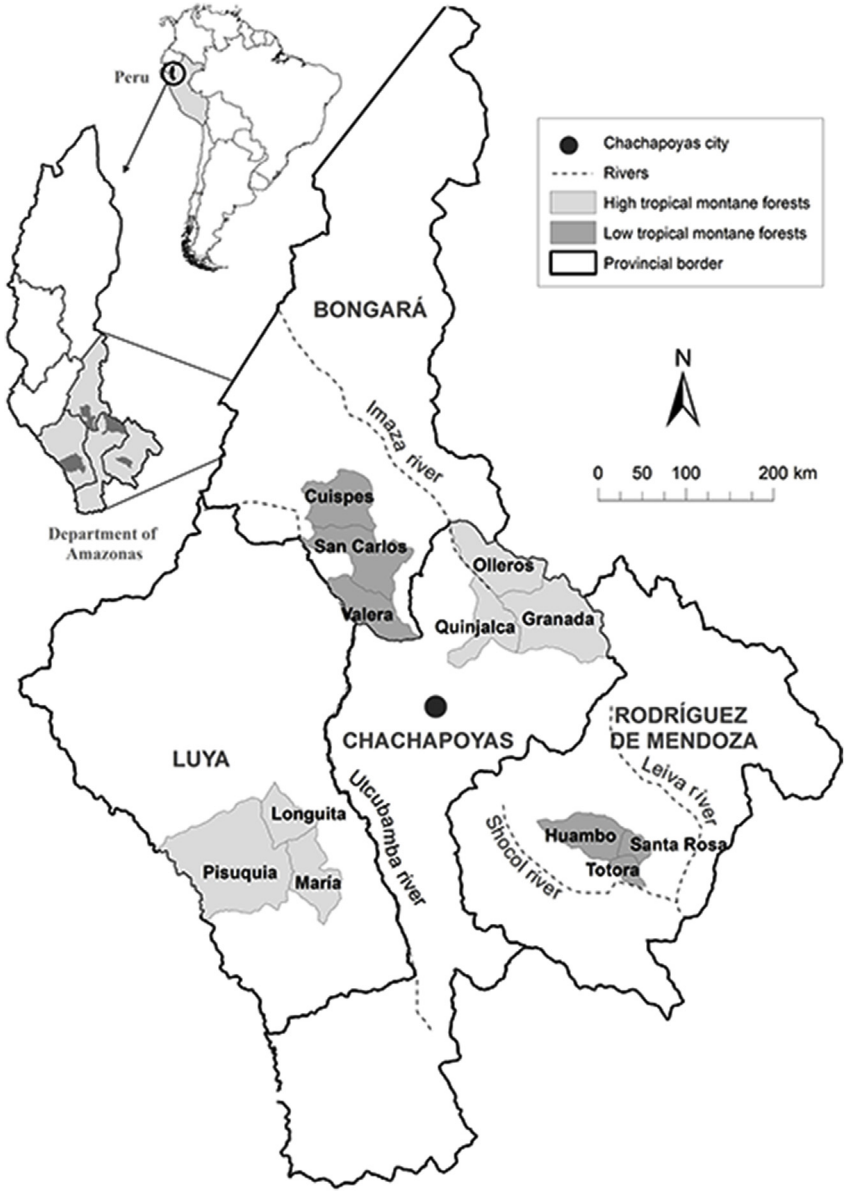

Fig. 1. Map of the study area in northern Peruvian Andes showing the two ecoregions (high and low tropical montane forests), the four areas, and the 12 localities where medicinal plants uses were gathered in 600 interviews.

and > 60 years old. In the locality of Granada we could only interviewed to one informant > 60 years.

All collected specimens were deposited in the Herbarium Truxillense (HUT) with duplicates at the Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas (Peru). The scientific names followed *The Plant List* (The Plant List, 2018) and the family taxonomic classification followed the *Angiosperm Phylogeny Group* (Byng et al., 2016).

2.3. Ethics statement

Research was carried out according to the Convention of Biological Diversity taking into account the Bonn guidelines and the Nagoya Protocol (SCBD, 2002, 2011). A written permission was obtained from each locality leader. Informed consent was orally obtained from all participants and before conducting interviews. Interviewees could stop responding at any time and were informed that all data provided would be anonymized. The ethics committee of the Autonomous University of Madrid aproved this statement (CEI 73–1327 to M.J. Macía).

2.4. Data analysis

All the medicinal indications were classified into 18 categories following international standards (Cook, 1995) with additional modifications to adapt them to tropical regions and to include properly cultural diseases (Macía et al., 2011; Gruca et al., 2014) (Appendix A). To evaluate TK on medicinal plants across localities, we used four ethnomedicinal indicators: total number of useful plant species, medicinal uses, medicinal use-reports, and average number of uses per species. We define (1) a “medicinal use” as the use of a plant part of a species that is associated with a medicinal category for a particular disease or ailment (Paniagua-Zambrana et al., 2014); and (2) a “medicinal use-report” as the medicinal use defined previously and associated to an informant.

To evaluate possible significant differences between highlands and lowlands, we use the 15 medicinal categories with the highest number of use-reports (200 or more) using general mixed linear models and its corresponding *post hoc* LSD Fisher test of multiple comparisons ($p < 0.05$). Similarly, we run analyses to compare TK between women

Table 1
Ethnomedicinal data gathered in two ecoregions, four areas, and 12 localities of the tropical montane forests of northern Peru.

Ecoregion	Areas	Localities	Elevation (m)	No. plant species	No. medicinal uses	No. use-reports	Average (± SD) number of uses per species	No. men interviewed	No. women interviewed
High tropical montane forests	All	All		354	2636	8628	5.9 (± 2.3)	152	148
	Chachapoyas	All		254	1192	4806	4.0 (± 2.4)	75	75
		Granada	3454	145	457	1459	2.9 (± 2.6)	25	25
		Olleros	3442	190	598	1613	2.8 (± 2.6)	27	23
		Quinjalca	3198	189	598	1734	2.7 (± 2.2)	23	27
	Luya	All		301	1673	3822	4.7 (± 2.5)	77	73
		María	2743	190	648	1244	3.0 (± 2.6)	27	23
		Longuita	2758	221	707	1246	2.8 (± 2.4)	24	26
		Yomblón	2920	210	729	1332	3.0 (± 2.9)	26	24
Low tropical montane forests	All	All		326	1638	5270	4.2 (± 2.2)	149	151
	Bongará	All		273	1187	3306	3.7 (± 2.1)	75	75
		Cuispes	1891	183	557	1258	2.6 (± 2.4)	25	25
		San Carlos	2013	175	476	1307	2.4 (± 2.0)	25	25
		Valera	1908	192	491	741	2.4 (± 2.2)	25	25
	Rodríguez de Mendoza	All		223	689	1964	2.7 (± 1.5)	74	76
		Santa Rosa	1759	145	282	613	1.7 (± 1.3)	26	24
		Totora	1655	146	332	995	2.0 (± 1.6)	23	27
		Huambo	1683	121	242	356	1.9 (± 1.3)	25	25

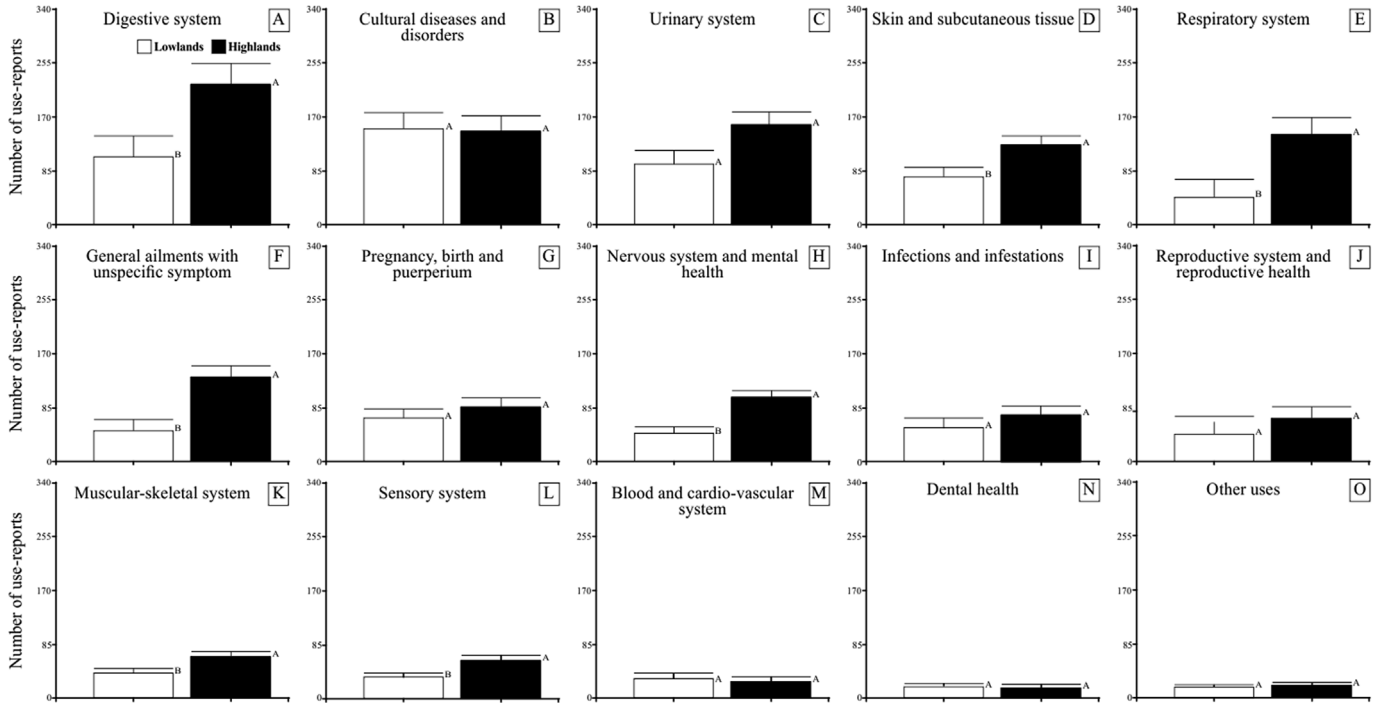

Fig. 2. Mean percentage of medicinal plants use-reports found comparatively in low tropical montane forests and high tropical montane forests based on 600 interviews in northern Peru. Letters (A, B) indicate significant differences based on general mixed lineal models and its corresponding *post hoc* LSD Fisher test ($p < 0.05$).

and men. Finally, to analyze TK transmission between age groups, we used the average percentages of use-reports per generation in mixed general linear models across localities. All analyses were performed in R 3.4.0. (R Development Core Team, 2017).

3. Results

3.1. Distribution of TK along the elevational gradient

A total of 13,898 use-reports, 3720 medicinal uses and 416 species belonging to 107 families were found in 600 interviews conducted in four areas, and 12 localities of two different ecoregions in the montane forests of northern Peru (Table 1). Medicinal plants and uses are shown in the supplementary material. Comparatively, 354 species and 8628 use-reports were mentioned in the highlands and 326 species and 5270 use-reports in the lowlands. The most representative families in the highlands were Compositae (12.3% of total use-reports), Lamiaceae (10.7%) and Solanaceae (6.3%), whereas in the lowlands were Lamiaceae (13.5%), Compositae (9.8%) and Rutaceae (7.3%). The most cited species in the highlands were *Minthostachys mollis* (Benth.) Griseb. (3.7% of total use-reports), *Matricaria recutita* L. (3.6%) and *Citrus limon* (L.) Osbeck (2.8%), whereas in the lowlands were *Minthostachys mollis* (6.2%), *Citrus limon* (3.3%) and *Ruta chalepensis* L. (2.4%). On the other hand, the most versatile species in the highlands were *Citrus limon*, cited for uses in 15 medicinal categories, followed by *Erythroxylum coca* Lam. and *Ruta chalepensis*, both cited in 14 medicinal categories. Similarly, in

the lowlands the most versatile species were *Citrus limon*, cited for uses in 14 medicinal categories, followed by *Matricaria recutita* and *Ruta chalepensis*, both cited in 11 medicinal categories. The species *Sambucus peruviana* Kunth, *Ullucus tuberosus* Caldas, and *Physalis peruviana* L. were highly used in the highlands and just marginally used in the lowlands, whereas *Bixa orellana* L., *Passiflora edulis* Sims and *Ocimum basilicum* L. were highly used in the lowlands and rarely in the highlands.

In general terms, people in the highlands had higher TK than in the lowlands, according to the four ethnomedicinal indicators used (Table 1). Rodríguez de Mendoza (lowlands) was the area that showed the lowest numbers of TK. In Bongará (lowlands), we found a higher number of plant species than in Chachapoyas (highlands), but the other three ethnomedicinal indicators were lower. Within the highlands, Luya scored higher in three out of the four indicators, only surpassed by Chachapoyas in the number of use-reports.

In the highlands, 12 out of 18 medicinal categories showed higher number of use-reports than in the lowlands with *Digestive*, *General ailments, Nervous* and *Respiratory systems* cited more than double (Fig. 2A, 2E, 2F and 2H). The remaining six medicinal categories scored higher in the lowlands, but most of them were among the categories with the lowest number of use-reports. *Cultural diseases and disorders* (Fig. 2B) and *Ritual and magic uses* (data not shown) showed slightly higher values in the lowlands. The two areas in the highlands showed similar values of use-reports: Chachapoyas scored higher in nine categories whereas Luya did so in the other nine categories. However, in the lowlands, Bongará showed higher values of use-reports in all categories compared to Rodríguez de Mendoza.

Significant statistically differences were found in seven out the 15 most cited categories along the elevational gradient: *Digestive system*, *General ailments*, *Muscular-skeletal system, Nervous system*, *Respiratory system*, *Sensory system* and *Skin and subcutaneous tissue* (Fig. 2A, 2D, 2E, 2F, 2H, 2K and 2L). All these categories scored higher in the highlands. Among the eight categories that did not have significant statistically differences between ecoregions, three of them showed higher percentages of use-reports in the lowlands (*Blood and cardio-vascular system, Cultural diseases and disorders*, and *Dental health*) (Fig. 2B, 2M and 2N), and five categories in the highlands (*Infections and infestations, Pregnancy, birth and puerperium*, *Reproductive system and reproductive health, Urinary system* and *Other uses*) (Fig. 2C, 2G, 2I, 2J and 2O).

3.2. Gender distribution of TK on medicinal plants

Overall, women showed a higher percentages of use-reports in all medicinal categories and areas in both ecoregions with the exception of *Cultural diseases and disorders* in Luya province (Fig. 3B), and *Muscular-skeletal system* and *Urinary system* in Luya and Rodríguez de Mendoza (Fig. 3C). We found significant statistically differences in the distribution of TK between men and women in all medicinal categories except in *Cultural diseases and disorders*, *Dental health* and *Muscular-skeletal system* (Fig. 3B, 3N and 3K). Women cited more than double use-reports than men in the categories of *Blood and Cardio-vascular system*, *Pregnancy, childbirth and puerperium* and *Reproductive system*, with the exception of Luya province (Fig. 3G, 3J and 3M). This was also the case in *Metabolic system* and *Ritual and magical uses* (data not shown).

Basically, women and men used the same most versatile medicinal species. The most used species by women were *Minthostachys mollis* (2.5% of total use-reports), *Matricaria recutita* (1.9%), *Citrus limon* (1.6%) and *Ruta chalepensis* (1.6%), whereas by men were similar: *Minthostachys mollis* (2.1% of total use-reports), *Citrus limon* (1.4%), *Matricaria recutita* (1.2%) and *Plantago major* L. (1.2%).

3.3. TK transmission across age groups

In the highlands, the TK of medicinal plants increased from the youngest (18–30 years) to the senior group (51–60 years), with a slight decreasing for those over 60 years in all localities (Fig. 4A–F) where statistically significant differences were found across groups. In the lowlands, the findings were less clear. In the Totora and Huambo localities, the pattern was similar to the highlands (Fig. 4K–L), but was not statistically significant. However in two other localities (Cuispes and San Carlos), the highest TK was recorded in the elders age group (Fig. 4G and 4H), whereas in Valera and Santa Rosa, the highest TK was reported in the middle age groups (Fig. 4I and 4J), although only in two of these cases were statistically significant (Fig. 4H and 4I). It is surprising the high percentage of use-reports found in Valera for the senior group (51–60 years), which represented more than double than the other four groups (Fig. 4I).

Minthostachys mollis, *Matricaria recutita* and *Citrus limon* were the three species most highly used across generations. *Plantago major* was very used for the three younger age groups, whereas *Melissa officinalis* L. was so for the 31–50 years generations, and *Erythroxylum coca* and *Sambucus peruviana* for the 41–60 age groups.

4. Discussion

4.1. Elevational gradient

Traditional medicine is still widely practiced in the tropical montane forests of northern Peru. We found a higher number of medicinal species and medical indications than previuos studies in other Andean regions of the country (Hammond et al., 1998; De la Cruz et al., 2007; Huamantupa et al., 2011; Monigatti et al., 2013; Gonzales et al., 2014). Several factors can explain these results including the large area covered in our study, the stratified sampling across different age groups, the gender balance of the interviewers, the high number of informants, and the special focus posed on the expert informants.

The TK on medicinal plants was higher in the highlands than in the lowlands, which accept our first hypothesis. This can be explained by at least four variables. First, the socio-economic factors differentiate clearly the population in the ecoregions, being the lowlands more prosperous with permanent crops, land suitable for forestry production, fishing areas and greater economic income coming from tourism (Almeida et al., 2010). On the contrary, the economic resources in the highlands are more scarce, with predominance of subsistence crops or based on milk production of extensive beef cattle farming. So, areas with greater socio-economic development tend to be areas with lower TK on medicinal plants, such as the case of Rodríguez de Mendoza, that also have been reported in other studies (Kunwar and Bussmann, 2008; Lira et al., 2009; Vandebroek, 2010). Second, migration processes to urban areas. In the lowlands it took place mainly from the 90s, whereas in the highlands occurred only from the last decade (INEI, 2008, 2009). Migration use to cause rapid cultural and socio-economic changes that usually produce the loss of TK from one generation to the next (Takasaki et al., 2001; Reyes-García et al., 2013), which surely ocurred in the lowlands by a reduction in the use of medicinal plants. Third, the isolation of the localities in the highlands and the lack of health services and infrastructures resulted in a more prominent use of the traditional medicine as previously have been reported in other studies (Benz et al., 2000; Byg et al., 2007; Leonard et al., 2015). Fourth, the environmental conditions of the two ecoregions. In the highlands, the population is living in a more adverse and extreme climatic conditions than the population in the lowlands, and probably have produced more ailments and disorders of the *Respiratory system* (De la Cruz et al., 2007), and *General diseases*, such as fever and headache (D'Arcy, 2004). At the same time, remedies for disorders and diseases of the *Digestive* and *Urinary systems* were mainly found in the highlands. This can be explained because they have not implemented water treatment for human consumption that surely affect more assiduously to their gastrointestinal and urinary problems (Collins et al., 2006; Pareek and Kumar, 2013). Concerning *Cultural diseases and disorders*, TK was widely shared in both ecoregions with slightly higher values in the lowlands. This medicinal category includes diseases like *susto*, *gentil*, *tacsho*, *tijte, pulsario*,

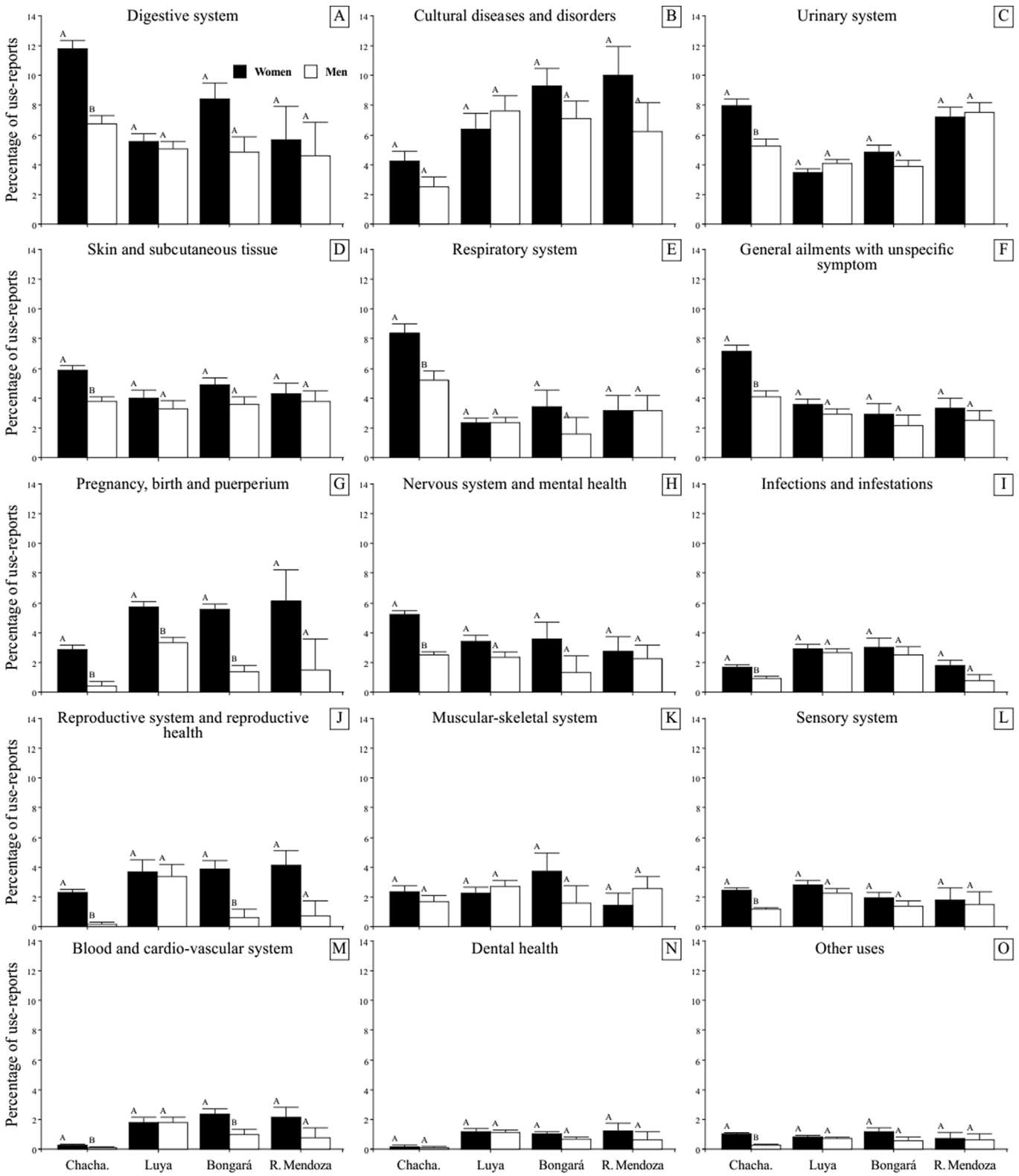

Fig. 3. Mean percentage of medicinal plants use-reports analyzed between women and men for four areas and the 12 localities in northern Peruvian Andes. Letters (A, B) indicate significant differences based on general mixed lineal models and its corresponding *post hoc* LSD Fisher test ($p < 0.05$).

shucaque, *shadow* or *dispela* that came from traditional Andean medicine and are not treatable with the conventional medicine. However, traditional medicine treat them with medicinal plants (e.g. Macía et al., 2005; Mathez-Stiefel et al., 2012; Gonzales et al., 2014).

In contrast with the results found in the provinces of Rodríguez de Mendoza and Chachapoyas, the localities of Bongará (lowlands) showed a similar TK than the localities of Luya (highlands). This can be explained by geographic, touristic and commercial factors. First, the road communication between the localities in Bongará and the localities in Luya (with the exception of Yomblón), has been recently

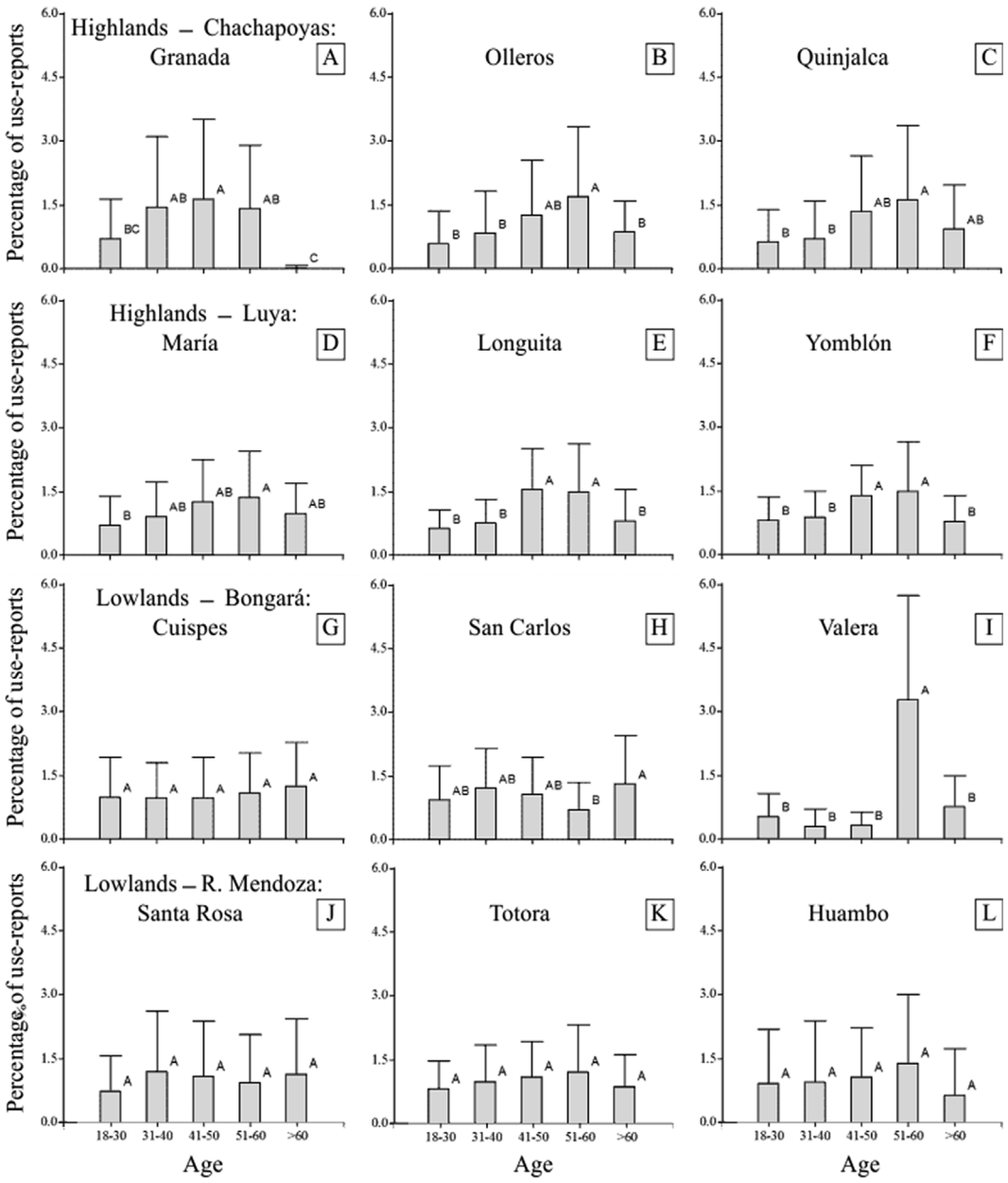

Fig. 4. Mean percentage of medicinal plants use-reports broken down by five age cohorts in six localities in the highlands (A–F) and six localities in the lowlands (G–L) in the northern Andes of Peru. Letters (A, B, C) indicate significant differences based on general mixed lineal models and its corresponding *post hoc* LSD Fisher test ($p < 0.05$).

paved and then has enabled the communication of people between both areas, generating a flow of information that also facilitates the exchange of TK. Second, both areas have the two most visited tourist sights in the Department of Amazonas: Kuélap prehispanic archaeological complex in Luya and the Gocta waterfall (771 m) in Bongará. These two tourist attractions have produced an increase in the number of visitors in these two provinces, which have increased the services offered and therefore have produced better economic development among its inhabitants, respectively. Third, one of the most important street markets in the ecoregion is weekly organized between the two areas, and regularly attracts merchants and buyers from the six locations, which again facilitate the transfer of knowledge and could have conformed a major similarity in TK between the areas (Gazzaneo et al., 2005).

The most cited plant families in our study are included among the most important in other Andean medicinal plants works, being Compositae as the family with the highest number of medicinal species, and Lamiaceae, Solanaceae and Leguminosae among the most important families (e.g. Fernandez et al., 2003; Tene et al., 2007). The same applies for the most used species in both ecoregions. *Minthostachys mollis*, *Matricaria recutita*, *Ruta chalepensis*, *Citrus limon*, *Plantago major* and *Erythroxylum coca* are commonly cited in any Andean ethnomedicinal work for similar uses (e.g. Bussmann and Sharon, 2006; Armijos et al., 2014; Gonzales et al., 2014). On the other hand, species more suitable in the highlands such as *Sambucus peruviana*, *Ullucus tuberosus* and *Physalis peruviana* or species prevalently found in the lowlands such as *Bixa orellana*, *Passiflora edulis* and *Ocimum basilicum* showed great use differences between ecoregions. These differences can be explained by the easier availability of these species in one of the ecoregions and the prevalence of diseases associated to each ecoregion (Monigatti et al., 2013).

4.2. Gender and TK

Women are the keepers of the traditional medicinal knowledge in northern Peruvian Andes and therefore our hypothesis is accepted. This can be explain because women workplace is usually linked to their home, taking care of children and the elders, and to their homegardens and orchards (Coelho-Ferreira, 2009; Baliano et al., 2015). Often these homegardens are reservoirs of medicinal plants that women use as a family medicinal resource in most Andean societies (Finerman and Sackett, 2003). Many earlier studies conducted in the Andean regions are in line with our hypothesis, indicating that women are the main connoisseurs and transmitters of this TK in these countries (e.g. Perry and Gesler, 2000; Arango, 2004; Gonzales et al., 2014; Zambrano et al., 2015). The role of women is almost exclusive in the application of medicinal plants in some domains, such as *Pregnancy, childbirth and puerperium* and *Reproductive system* (Vandebroek et al., 2010; Malan and Neuba, 2011; Barreto and Schultze-Kraft, 2014).This knowledge is only limited to expert men informants in our study. However, there are other works in which men showed a greater TK on medicinal plants which resulted from the division of responsibilities (Paniagua-Zambrana et al., 2014) or due to their greater participation in agriculture or livestock activities (Vandebroek et al., 2004; Albuquerque et al., 2011). So future conservation programs should mainly focus on women to preserve the traditional medicine in this Andean ecoregions.

4.3. Age and transmission of TK on medicinal plants

In the highlands and some localities of the lowlands, the TK on medicinal plants increased from the youngest to the seniors and then decreasing progressively to the elders, so our hypothesis that elders have a greater TK than youngers is only partially accepted. This general pattern is also found in other studies throughout the world where older people are less affected by external influences, and therefore maintain their beliefs and TK acquired in the past (Byg and Balslev, 2004; Zabihullah et al., 2006; Srithi et al., 2009; Menendez-Baceta et al., 2014; Paniagua-Zambrana et al., 2016). Nevertheless, there is a lack of consensus on the relationship between age and TK on medicinal plants (Almeida et al., 2015). Some factors that explain this diacronic TK are related to the loss of interest from younger generations in traditional medicine (Eyssartier et al., 2008) and the more common use of medicaments that produce more rapid effects to alleviate diseases or ailments (Giday et al., 2003).

During the last 20 years, basic medical posts have been implemented in each of the studied localities in both ecoregions. It can be an explanation for the loss of knowledge among younger groups, because they had an easier access to the conventional medicine services which may entail to not use TK on medicinal plants (Ayantunde et al., 2008; Ladio and Lozada, 2009; McMillen, 2012). This pattern is clear in all the studied localities in the highlands but only happen in some localities of the lowlands. The other localities of the lowlands are suffering the abandonment of their TK on medicinal plants in a clearer way, and this loss seems to be identified in most of the age groups. Furthermore, in these lowlands localities the socioeconomic conditions are better than in the highlands localities, and people have the oportunity to choose between conventional medical treatment or traditional medicine based on medicinal plants.

Concerning the great difference of TK in Valera for people between 51 and 60 years old and the other age groups, it is simply because the majority of the experts interviewed in this locality fall in this generation.

The great use that is made in the five age groups of *Minthostachys mollis*, *Matricaria recutita* and *Citrus limon* can be explained because these species were frequently reported in two of the most cited categories across generations, *Digestive system* and *Cultural diseases and disorders*, where they are widely used species. It is also remarkable, the medicinal use of *Erythroxylum coca* which is increasing with age based surely on its great cultural importance from ancient times (Martin, 1970). However, the use for generations over 60 years is considerably reduced, and probably is due to their alienation from the hard work of livestock and agricultural activities (Maina, 2012).

Finally, future national or international programs dedicated to the conservation of TK on medicinal plants should understand first, who are the depositaries generations that mostly retain the TK before dedicate any economic effort and support. And please, do not assume that elders are always the only depositaries of the TK across areas and regions.

5. Conclusions

The high number of medicinal species and use-reports showed the importance of TK on medicinal plants in the northern Andes of Peru. Ecoregions with the lowest socioeconomic development are related to a greater TK on medicinal plants, so it is highly relevant for their livelihoods. Women are key custodians of medicinal plants and repositories of TK for the good health of the families. Overall, this knowledge is mainly found in the elders and is not being transmitted to the new generations uniformly. However, this study shows that TK on medicinal plants is still alive and its divergent tranmission is preventing its rapid loss. Future biocultural conservation programmes could integrate this low cost TK based on medicinal plants, for local and regional population development and for the improvement of their ways of life.

Author contributions

FC and MJM conceived the ideas, FC collected the data, FC, OG and MJM analysed the data and FC and MJM wrote the manuscript. All authors approved the final version of the manuscript.

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Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jep.2019.111924.

Appendix A. Total number of use-reports (minimum, maximum) of the medicinal plants documented in two ecoregions, four areas, and 12 localities of the tropical montane forests in northern Peru. Medicinal uses are classified in 18 medicinal categories according to Cook (1995), Macía et al. (2011) and Gruca et al. (2014).

	High Tropical Montane Forests			Low Tropical Montane Forests			
Categories/Subcategories	Chachapoyas	Luya	All	Bongará	R. Mendoza	All	Total
Digestive system	888 (266–331)	404 (115–151)	1292	451 (78–189)	174 (34–72)	625	1917
Diarrhoea	170 (49–67)	125 (33–50)	295	114 (17–55)	34 (6–17)	148	443
Stomach pain	370 (74–155)	4 (0–4)	374	51 (8–24)	7 (0–5)	58	432
Liver disorders	132 (31–56)	51 (11–24)	183	23 (4–14)	18 (2–10)	41	224
Stomach cramps	26 (0–26)	51 (10–21)	77	68 (5–35)	41 (4–23)	109	186
Laxative	43 (11–17)	56 (13–24)	99	63 (14–28)	8 (1–4)	71	170
Carminative	65 (14–31)	35 (1–18)	100	23 (5–12)	20 (4–9)	43	143
Stomach infection	44 (11–17)	4 (0–4)	48	26 (1–18)	7 (0–7)	33	81
Gastric ulcers	9 (2–5)	21 (5–9)	30	33 (5–16)	8 (0–8)	41	71
Digestive	19 (0–1)	16 (3–9)	35	13 (3–6)	4 (0–3)	17	52
Hepatitis	2 (0–1)	15 (2–8)	17	23 (2–11)	5 (0–4)	28	45
Constipation	6 (0–5)	20 (4–11)	26	–	5 (0–4)	5	31
Indigestion	–	4 (1–2)	4	8 (0–8)	11 (0–11)	19	23
Intestinal infection	1 (0–1)	–	1	5 (0–4)	–	5	6
Gallbladder	–	2 (0–2)	2	–	2 (0–2)	2	4
Stomach sickness	–	–	–	–	4 (0–3)	4	4
Acidity	1 (0–1)	–	1	–	–	–	1
Antiemetic	–	–	–	1 (0–1)	–	1	1
Cultural diseases and disorders	**324 (87–139)**	**538 (158–216)**	**862**	**557 (113–224)**	**330 (37–148)**	**887**	**1749**
Susto, espanto	65 (21–23)	73 (15–35)	138	101 (14–57)	204 (16–99)	305	443
Antimonia, gentil, viejo, antiguo	17 (1–11)	180 (36–100)	197	145 (37–68)	33 (0–20)	178	375
Aire, malaire	186 (55–74)	71 (13–33)	257	99 (14–44)	5 (0–3)	104	361
Tacsho	36 (9–16)	123 (33–47)	159	115 (31–42)	42 (6–20)	157	316
Tijte	7 (1–5)	51 (10–25)	58	53 (5–27)	38 (0–20)	91	149
Pulsario	–	30 (7–12)	30	29 (3–17)	7 (0–5)	36	66
Negative vibes	1 (0–1)	5 (0–5)	6	9 (1–5)	1 (0–1)	10	16
Shucaque	5 (0–5)	5 (0–5)	10	3 (0–2)	–	3	13
Shadow	5 (0–3)	–	5	3 (0–3)	–	3	8
Dispela	2 (0–2)	–	2	–	–	–	2
Urinary system	**633 (190–238)**	**290 (89–101)**	**923**	**285 (68–121)**	**277 (62–133)**	**562**	**1485**
Kidney disorders, emollient, diuretic	564 (164–214)	192 (59–67)	756	184 (43–73)	186 (49–84)	370	1126
Prostate disorders	33 (9–15)	83 (16–37)	116	91 (23–45)	85 (7–46)	176	292
Kidney stones	36 (10–15)	15 (4–6)	51	10 (2–5)	6 (1–3)	16	67
Skin and subcutaneous tissue	**460 (138–167)**	**276 (87–101)**	**736**	**284 (58–115)**	**155 (33–81)**	**439**	**1175**
Wounds, healing	306 (96–105)	74 (12–32)	380	87 (18–35)	21 (2–17)	108	488
Chirapa	26 (2–13)	97 (26–37)	123	5 (0–5)	45 (5–22)	50	173
Burns	2 (0–1)	67 (20–24)	69	74 (12–31)	17 (0–15)	91	160
Swelling	118 (18–53)	2 (0–2)	120	23 (3–11)	8 (0–5)	31	151
Itil	–	12 (0–8)	12	62 (14–25)	49 (2–32)	111	123
Acne	1 (0–1)	15 (1–12)	16	11 (1–5)	11 (0–10)	22	38
Feet fungus	1 (0–1)	8 (0–6)	9	20 (3–11)	2 (0–1)	22	31
Liver spots	6 (1–4)	1 (0–1)	7	1 (0–1)	2 (0–2)	3	10
Wrinkles	–	–	–	1 (0–1)	–	1	1
Respiratory system	**654 (196–260)**	**178 (48–71)**	**832**	**148 (40–63)**	**110 (25–49)**	**258**	**1090**
Cold	262 (64–111)	46 (10–20)	308	28 (5–15)	36 (6–17)	64	372
Flu	93 (25–40)	89 (23–40)	182	86 (24–32)	51 (8–25)	137	319
Cough	196 (58-75	15 (2–7)	211	15 (4–6)	18 (1–11)	33	244
Tonsillitis	50 (14–20)	1 (0–1)	51	8 (1–6)	2 (0–2)	10	61
Bronchitis	34 (4–16)	5 (0–4)	39	4 (0–4)	2 (0–2)	6	45
Expectorant	7 (1–4)	10 (2–6)	17	5 (1–2)	–	5	22
Sinusitis	3 (0–2)	10 (2–5)	13	–	–	–	13
Asthma	9 (1–7)	–	9	1 (0–1)	1 (0–1)	2	11
Bad breath	–	1 (0–1)	1	1 (0–1)	–	1	2
Aphonia	–	1 (0–1)	1	–	–	–	1
General ailments with unspecific symptoms	**535 (168–184)**	**248 (76–90)**	**783**	**172 (31–93)**	**111 (21–63)**	**283**	**1066**
Fever	300 (91–108)	196 (58–75)	496	141 (25–70)	88 (14–54)	229	725
Headache	180 (54–67)	23 (4–11)	203	6 (1–4)	6 (0–4)	12	215
General malaise	19 (0–19)	22 (4–12)	41	20 (0–19)	12 (0–9)	32	73
Energizing	36 (9–14)	7 (2–3)	43	5 (1–3)	5 (1–2)	10	53
Pregnancy, birth and puerperium	**160 (32–71)**	**346 (106–123)**	**506**	**231 (51–91)**	**170 (6–87)**	**401**	**907**
Birth	73 (17–31)	116 (32–44)	189	85 (20–37)	54 (4–28)	139	328
Breastfeeding	53 (8–27)	107 (33–38)	160	63 (10–27)	61 (2–42)	124	284
Postpartum	23 (3–13)	95 (22–39)	118	72 (17–31)	53 (0–30)	125	243
Abortive	11 (1–6)	28 (4–13)	39	11 (3–4)	2 (0–2)	13	52
Nervous system and mental health	**372 (115–131)**	**222 (59–92)**	**594**	**154 (44–63)**	**107 (14–66)**	**261**	**855**
Insomnia	158 (45–58)	73 (16–30)	231	55 (5–27)	29 (3–21)	84	315
Sadness	106 (32–37)	86 (20–34)	192	31 (6–14)	45 (4–27)	76	268
Stress	93 (29–34)	50 (8–23)	143	49 (5–22)	32 (6–18)	81	224
Mental stimulant	15 (4–6)	7 (1–4)	22	11 (0–9)	1 (0–1)	12	34
Epilepsy	–	6 (1–3)	6	8 (0–4)	–	8	14

Infections and infestations	**129 (34–48)**	**300 (81–123)**	**429**	**237 (52–103)**	**79 (7–52)**	**316**	**745**
Intestinal parasites	116 (32–43)	73 (21–27)	189	94 (12–47)	44 (1–28)	138	327
Chickenpox	–	82 (18–42)	82	40 (8–19)	2 (0–1)	42	124
Fleas	–	54 (12–23)	54	20 (1–14)	20 (0–18)	40	94
UTA, leishmaniasis	4 (0–3)	14 (1–9)	18	40 (6–20)	2 (0–1)	42	60
Malaria	1 (0–1)	38 (4–20)	39	6 (0–5)	1 (0–1)	7	46
Insect bite	–	15 (3–8)	15	13 (2–8)	5 (0–4)	18	33
Tick bite	1 (0–1)	14 (3–6)	15	18 (1–13)	–	18	33
Yellow fever	7 (1–4)	5 (0–3)	12	4 (0–4)	1 (0–1)	5	17
Lice	–	2 (0–2)	2	1 (0–1)	1 (0–1)	2	4
Herpes	–	–	–	–	3 (0–3)	3	3
Smallpox	–	3 (0–3)	3	–	–	–	3
Tuberculosis	–	–	–	1 (0–1)	–	1	1
Reproductive system and reproductive health	**117 (30–46)**	**272 (60–121)**	**389**	**144 (41–61)**	**93 (13–47)**	**237**	**626**
Menstruation disorders	101 (26–38)	177 (35–97)	278	105 (31–43)	85 (11–42)	190	468
Menopause	–	36 (7–16)	36	20 (5–12)	1 (0–1)	21	57
Fertility	–	26 (4–15)	26	7 (1–4)	6 (0–5)	13	39
Impotence	–	21 (4–13)	21	2 (0–1)	1 (0–1)	3	24
Vaginal infection	16 (3–9)	3 (0–3)	19	4 (0–4)	–	4	23
Contraceptive	–	6 (1–3)	6	5 (0–5)	–	5	11
Aphrodisiac	–	3 (0–3)	3	–	–	–	3
Sexual infections	–	–	–	1 (0–1)	–	1	1
Muscular-skeletal system	**197 (36–88)**	**188 (53–80)**	**385**	**161 (45–59)**	**72 (19–33)**	**233**	**618**
Broken bones	80 (20–36)	89 (23–41)	169	62 (16–27)	43 (5–27)	105	274
Rheumatism	86 (11–38)	82 (25–32)	168	63 (18–24)	23 (7–10)	86	254
Joint sprains	13 (2–9)	6 (1–4)	19	11 (3–4)	1 (0–1)	12	31
Bones hardening	11 (1–7)	1 (0–1)	12	13 (0–12)	–	13	25
Hernia	1 (0–1)	10 (1–6)	11	12 (1–9)	–	12	23
Muscle cramps	6 (2–2)	–	6	–	–	–	6
Lumbago	–	–	–	–	5 (0–5)	5	5
Sensory system	**174 (56–61)**	**193 (57–74)**	**367**	**116 (15–53)**	**82 (1–59)**	**198**	**565**
Visual disorders	154 (50–52)	118 (35–44)	272	64 (7–29)	38 (0–27)	102	374
Hearing disorders	20 (5–9)	75 (22–30)	95	52 (8–25)	44 (1–32)	96	191
Blood and cardio-vascular system	**19 (6–7)**	**135 (37–52)**	**154**	**114 (19–53)**	**65 (5–39)**	**179**	**333**
High pressure	10 (1–7)	35 (7–20)	45	45 (2–24)	29 (2–16)	74	119
Anemia	1 (0–1)	55 (16–21)	56	30 (2–15)	17 (1–14)	47	103
Low pressure	–	22 (7–8)	22	15 (3–11)	10 (0–5)	25	47
Hemorrhoids	2 (0–1)	10 (1–6)	12	16 (3–9)	6 (1–4)	22	34
Blood infection	3 (0–3)	6 (0–6)	9	6 (1–3)	–	6	15
Varicose veins	–	7 (0–4)	7	2 (0–2)	3 (0–2)	5	12
Blood purifying	3 (0–3)	–	3	–	–	–	3
Dental health	**12 (2–7)**	**87 (20–36)**	**99**	**58 (9–27)**	**43 (0–22)**	**101**	**200**
Toothache	1 (0–1)	87 (20–36)	88	57 (8–27)	43 (0–22)	100	188
Cavity	8 (0–5)	–	8	1 (0–1)	–	1	9
Gingivitis	2 (0–2)	–	2	–	–	–	2
Oral sores	1 (0–1)	–	1	–	–	–	1
Metabolic system and nutrition	**22 (1–15)**	**56 (7–31)**	**78**	**54 (16–20)**	**48 (7–30)**	**102**	**180**
Weight loss	11 (0–7)	56 (7–31)	67	49 (13–20)	48 (7–30)	97	164
Whet	11 (1–8)	–	11	5 (0–5)	–	5	16
Ritual and magic uses	**43 (10–17)**	**2 (0–2)**	**45**	**50 (6–23)**	**9 (0–8)**	**59**	**104**
Remove envy	30 (8–13)	2 (0–2)	32	2 (0–1)	8 (0–8)	10	42
Curse	3 (0–3)	–	3	26 (5–11)	0 (0–0)	26	29
Bring good luck	–	–	0	22 (0–11)	1 (0–1)	23	23
Witchcraft	9 (0–9)	–	9	0 (0–0)	0 (0–0)	0	9
Hallucinogen	1 (0–1)	–	1	0 (0–0)	0 (0–0)	0	1
Endocrine system	**4 (0–2)**	**28 (5–16)**	**32**	**29 (4–16)**	**5 (1–3)**	**34**	**66**
Diabetes	4 (0–2)	28 (5–16)	32	28 (3–16)	5 (1–3)	33	65
Goiter	–	–	–	1 (0–1)	0 (0–0)	1	1
Other uses	**63 (16–25**	**59 (17–23)**	**122**	**61 (10–28)**	**34 (3–28)**	**95**	**217**
Hair loss	48 (12–21)	32 (8–13)	80	35 (6–18)	9 (0–8)	44	124
Cancer	7 (1–4)	21 (4–11)	28	25 (3–12)	24 (2–19)	49	77
Hangover	2 (0–2)	6 (0–5)	8	1 (0–1)	1 (0–1)	2	10
Deodorant	3 (0–3)	–	3	–	–	–	3
Altitude sickness	2 (0–2)	–	2	–	–	–	2
Anesthesia	1 (0–1)	–	1	–	–	–	1

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