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Observational Study

Limb Lengthening and Reconstruction Society orthopedic surgeons in the United States: An analysis of geographical distribution, academic, leadership, and demographic characteristics

Amir Human Hoveidaei, Reza Niakan, Seyed Hossein Hosseini-Asl, Abijith Annasamudram, Janet D Conway

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Abstract

BACKGROUND

The Limb Lengthening and Reconstruction Society (LLRS) is a premier orthopedic specialty organization that promotes limb reconstruction for all ages. LLRS membership characteristics, however, are poorly reported. This study delineates orthopedic surgeon LLRS members' demographic traits, academic achievement, leadership attainment, and geographical distribution across the United States.

AIM

To inform aspiring orthopedic professionals, as well as to promote growth and diversity in both the LLRS organization and overarching field.

METHODS

This cross-sectional study examined United States LLRS members' academic, leadership, demographic, and geographical attributes. After reviewing the 2023 LLRS member directory, Google search results were matched to the listings and appended to the compiled data. Sex and ethnicity were evaluated visually utilizing retrieved images. The Hirsch index (H-index) of academic activity, residency and fellowship training, other graduate degrees, leadership positions, practice type (academic or non-academic), and spoken languages were categorized. LLRS members per state and capita determined geographic distribution. The Mann-

Whitney *U* test was applied to compare H-index between males and females, as well as to assess member differences pertaining to affiliation with academic *vs* non-academic practice facilities.

RESULTS

The study included 101 orthopedic surgeons, 78 (77.23%) Caucasian and 23 (22.77%) non-Caucasian, 79 (78.22%) male and 22 (21.78%) female. Surgeons with DO degrees comprised only 3.96% (4) of the cohort, while the vast majority held MDs [96.04% (97)]. Mean H-index was 10.55, with male surgeons having a significantly higher score ($P = 0.002$). Most orthopedic surgeons (88.12%,) practiced in academic centers. Of those professionals who occupied leadership positions, 14% were women, while 86% were men. Additionally, 19 (37.25%) United States regions and the District of Columbia lacked an LLRS-member orthopedic surgeon. Total per capita rate across the United States was 0.30 LLRS orthopedic surgeons per 1 million people.

CONCLUSION

Over 21% of LLRS members are women, surpassing prior benchmarks noted in orthopedic faculty reporting. LLRS members' high research productivity scores imply field dedication that can refine expertise in the limb lengthening and reconstruction space. Gender disparities in leadership remain, however, necessitating greater equity efforts. A low rate of LLRS representation per capita must be addressed geographically as well, to affect improvements in regional care access. This study can serve to support aspiring orthopedic professionals, inform diversity, leadership, and field advancement strategies, and maintain the continued goal of enhanced patient care worldwide.

Key Words: Limb lengthening and reconstruction; Orthopedic surgeon demographics; Orthopedic surgeon societal membership; Orthopedic fellowships

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Core Tip: Societal membership characteristics for the Limb Lengthening and Reconstruction Society had previously been poorly reported. These attributes were analyzed comparatively with industry precedents to glean insights for aspiring orthopedic professionals, inform organizational decision-making in support of growth, diversity, and equity, as well as to uphold the foundational goal of patient care optimization.

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INTRODUCTION

The Limb Lengthening and Reconstruction Society (LLRS) is a prominent orthopedic specialty society operating within the American Academy of Orthopaedic Surgery (AAOS) volunteer structure. Initially founded in 1989 as the Association for the Study and Application of the Method of Ilizarov-North America, the LLRS is dedicated to advancing techniques to treat complex congenital and developmental deformities, as well as traumatic and post-traumatic limb conditions[1]. The organization has since been recognized as a branch of the AAOS's Board of Specialty Societies (1999), solidifying its stature as an instrumental entity in advancing the field of limb reconstruction for patients of all ages[2,3].

The LLRS encompasses a diverse, international group of orthopedic surgeons, physicians, and allied health professionals dedicated to encouraging research, scientific exchange, and collaboration. Leveraging the principles of distraction osteogenesis, its primary clinical focus is to deliver exceptional patient care for limb lengthening and reconstruction, extremity deformity correction, and complex fracture treatment[3,4].

The LLRS comprises 214 professionals, 49.5% (106) of whom reside in the United States. This membership base positions the LLRS as a pioneering authority within the United States[4,5]. Nevertheless, there remains a dearth of comprehensive reporting on leadership career paths within the field. Similar to other fields, positions of increasing organizational authority within the medical profession tend to be associated with certain distinguishing characteristics, such as innovation and specialization, scientific organization membership, research activity, mentorship, collaboration, and optimization of patient outcomes[6]. Objective criteria differentiating these exceptional individuals, and likewise those in LLRS leadership, remain elusive, however, engendering ambiguity about the specific qualifications needed to navigate such pathways to success[2,5].

On the other hand, sub-specialization and rising patient volumes have been extensively documented in other orthopedic fields[7]. The growing prevalence of motorized intramedullary lengthening nails for limb deformity correction

is one example of how surgical options have expanded in this relatively new subspecialty[8,9]. The treatment of limb deformity, and namely limb lengthening, has recently enjoyed increased recognition and understanding within the field. Nonetheless, the availability of such dedicated clinical services within academic orthopedic and societal institutions is still limited[10].

Considering this, the present study aims to achieve two primary goals. First, we want to identify the objective characteristics shared by LLRS members. Toward this end, we delve into the membership's demographics, institutional training backgrounds, and academic experiences, providing a useful framework for aspiring orthopedic professionals seeking similar career paths. In addition, we hope to shed light on the geographical distribution of LLRS members across the United States, highlighting areas where representation may be lacking, thus indicating opportunities for growth and diversity. We hypothesize that if there is diversity and gender-inclusivity among LLRS members, it may be associated with higher academic achievements within the society, compared to other orthopedic societies documented in the literature.

MATERIALS AND METHODS

Overview

This cross-sectional study utilized data from the LLRS directory to analyze members' academic, leadership, and demographic characteristics, as well as their geographical distribution in the United States. Excluded were 5 LLRS members who were not orthopedic surgeons. The study was deemed exempt by the institutional review board, as all data utilized were publicly available.

Data source

The 2023 LLRS member directory, accessed on May 22, 2023, was thoroughly reviewed to identify all LLRS-member professionals across the United States. Additional demographic data, including educational background, curriculum vitae, institutional biographies, and Scopus records, were collected *via* Google search.

To determine the population of each state in the United States, data from the United States Census Bureau was obtained.

Two evaluators (authors AHH and RN) independently assessed the data in a blinded manner. In cases of disagreement, findings were discussed in a mutual session and resolved by consensus.

Variables

Sex and ethnicity were defined based on the retrieved photographs, which had been matched to the membership listings where practicable. Ethnicity was categorized as Caucasian or non-Caucasian. Based on a previously documented method [11,12], "Caucasian" described visible characteristics consistent with persons of European or Caucasian descent. "Non-Caucasian" individuals displayed visible characteristics associated with diverse racial and ethnic backgrounds. This included those of African, Asian, Hispanic, Middle Eastern, Indigenous, and other non-European descent. We also endeavored to confirm categorization based on the additionally available data in the individuals' profiles.

Other variables included residency and fellowship training, and the member's H-index. H-index was obtained by querying the Scopus database (Elsevier BV, Waltham, MA, United States), which contains an extensive repository of peer-reviewed scientific literature, with a citation-tracking component.

In addition, this paper reports on other graduate degrees, leadership positions held, type of practice center (academic *vs* non-academic), and languages spoken other than English.

To derive the geographical distribution of LLRS members, totals per state were tallied. Calculations of per capita ratios were then performed using Census Bureau population statistics culled from the 9 divisions of the United States census Bureau.

Statistical analysis

Statistical analysis was conducted *via* Microsoft Office Excel 2019. LLRS member per capita values were assessed as the sum of LLRS members in a given area, divided by the total population of the corresponding state or census division, and scaled by a factor of 1000000 people. Tableau 2019.4.4 was utilized for geocoding labels.

To compare H-index between males and females, and between members practicing in academic or non-academic centers, the Mann-Whitney *U* test was applied using the SPSS version 26.0.

RESULTS

This study reviewed LLRS member listings for 101 orthopedic surgeons, 79 (78.22%) of whom were male, and 22 (21.78%) of whom were female. Seventy-eight (77.23%) were Caucasian, with the remainder belonging to non-Caucasian ethnicities. Only 4 (3.96%) held a DO degree, while 97 (96.04%) held an MD degree. Half of the DOs (2 of 4) had another graduate degree, whereas just 13 (13.40%) MDs had an additional graduate degree. Twenty-five individuals (27.75%) were reported to speak a second language, 36% of which was listed as Spanish fluency.

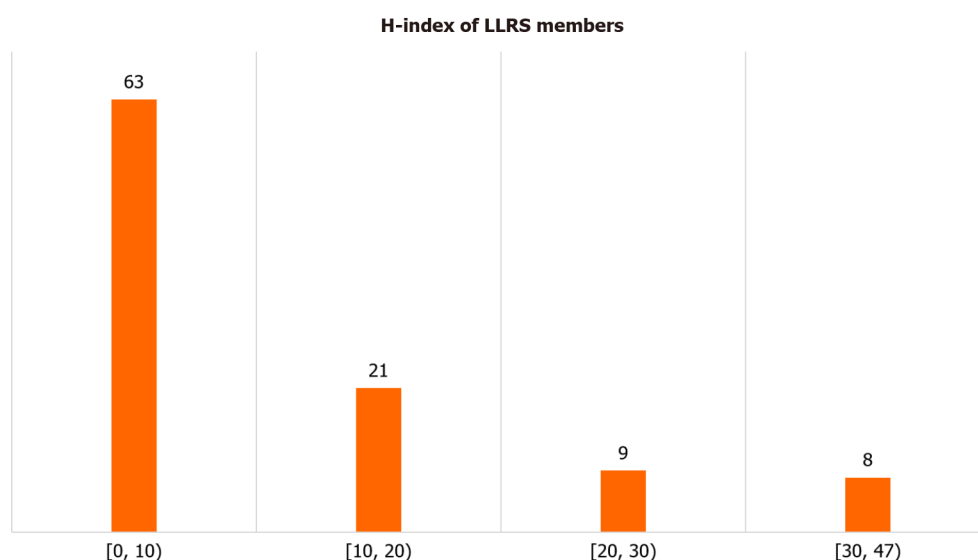


Figure 1 H-index of Limb Lengthening and Reconstruction Society members. LLRS: Limb Lengthening and Reconstruction Society.

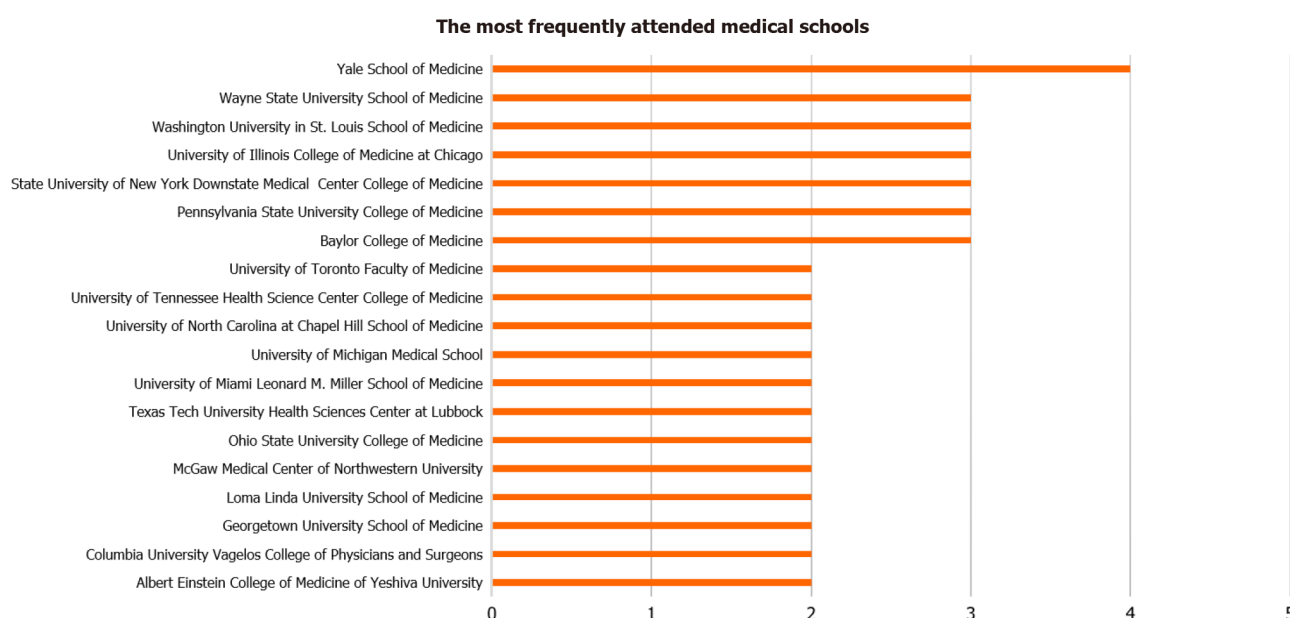


Figure 2 The most frequently attended medical schools.

In addition to the 3 Canadian school graduates, there were 11 surgeons who had graduated from international medical schools. Three of these schools were in India, and the others were situated in various countries. Most orthopedic surgeons worked in academic centers (89, 88.12%), while 12 (11.88%) did not. Average H-index was 10.55. Those who did not work in academic centers had a significantly lower mean H-index (2.00) than the others (11.71), ($P < 0.001$). The mean H-index for male surgeons was 12.03, as compared to 5.27 for females ($P < 0.002$). The Scopus H-indices of all LLRS members are depicted in [Figure 1](#).

Among the members evaluated, 28 held positions of leadership, such as department chair, society president, and clinic or fellowship director. Of these, 24 (85.71%) were men, and 4 (14.29%) were women.

Yale School of Medicine, Baylor College of Medicine, Pennsylvania State University College of Medicine, State University of New York Downstate Medical Center College of Medicine, University of Illinois College of Medicine at Chicago, Washington University in St. Louis School of Medicine, and Wayne State University School of Medicine, each produced at least 3 future LLRS orthopedic surgeons ([Figure 2](#)).

Cleveland Clinic Foundation and University of California (San Francisco) were the most frequently listed residency programs among LLRS members, with 4 LLRS members each, followed closely by Case Western Reserve University/University Hospitals Cleveland Medical Center, Icahn School of Medicine at Mount Sinai, and New York University School of Medicine/NYU Langone Orthopedic Hospital, at 3 per facility ([Figure 3](#)).

Table 1 Limb Lengthening and Reconstruction Society distribution of orthopedic surgeons across United States census divisions

| | Geographic region | LLRS orthopedic surgeons | LLRS orthopedic surgeons per 1 million people |
|------------------|--------------------|--------------------------|---|
| | Total | 101 | 0.30 |
| Northeast region | New England | 2 | 0.13 |
| | Middle Atlantic | 9 | 0.21 |
| Midwest region | East North Central | 12 | 0.25 |
| | West North Central | 5 | 0.23 |
| South region | South Atlantic | 29 | 0.44 |
| | East South Central | 5 | 0.26 |
| | West South Central | 14 | 0.34 |
| West region | Mountain | 6 | 0.24 |
| | Pacific | 19 | 0.35 |

LLRS: Limb Lengthening and Reconstruction Society.

Ninety-six (95.05%) of the 101 LLRS members evaluated had participated in at least one clinical fellowship during their professional career. These totaled 133, with 62 (46.62%) pediatric concentrations, 28 (21.05%) trauma-focused, 27 (20.30%) geared toward limb lengthening and reconstruction/deformity correction, 4 (3.01%) in musculoskeletal oncology, 4 (3.01%) for foot and ankle surgery, and 8 (6.01%) which included other types of fellowships. The International Center for Limb Lengthening (ICLL) at Sinai Hospital of Baltimore stood out as the program producing the most LLRS orthopedic surgeons pursuant to limb lengthening and reconstruction/deformity correction fellowships (excluding the LLRS traveling fellowship) (Figure 4).

There were no LLRS member orthopedic surgeons in 19 (37.25%) states. States with the most LLRS member orthopedic surgeons were California, Florida, Ohio, and Texas, with 13, 11, 9, and 9 members, respectively (Figure 5). The District of Columbia, Delaware, Alaska, and Oregon had the highest per capita numbers, with 2.90, 2.02, 1.36, and 1.18 LLRS orthopedic surgeons per 1 million population (Figure 6).

In the United States, the overall per capita rate of LLRS member orthopedic surgeons was 0.3 per 1 million people. Table 1 details the distribution of members across census divisions.

DISCUSSION

Gender equality in the LLRS compares favorably to recently reported findings in the literature. While the percentage of women holding orthopedic faculty positions and/or AAOS memberships has been purported to range from 6.5% to 10.5%, females comprised more than 21% of LLRS membership ranks[13,14].

Demographic distributions culled from orthopedic societies have noted an approximately 20.2% proportion of ethnic minorities among members, with even lower representation for the same groups in leadership positions. Similarly, an estimated 22.77% of LLRS members belong to non-Caucasian ethnicities[15].

The research and scientific productivity of LLRS members, as reflected by their H-index, is notable. While recent studies have reported a median H-index of 5 for academic orthopedic surgery faculty, the LLRS membership, including both academic and non-academic practitioners, had a higher median H-index of 6, and a mean of 10.55[16]. This demonstrates the overall higher research productivity of LLRS members compared to their academic counterparts. Additionally, the pattern of males being more productive in research aligns with the trends observed among the academic orthopedic surgery faculty[16-18].

Despite the encouraging female representation among LLRS members (21%), there remains a significant sex-related disparity in leadership roles, with only 14% of such titles held by women, *vs* an overwhelming majority (86%) which were occupied by men. This highlights the need for increased awareness to drive gender equality initiatives and promote equitable access to leadership opportunities, regardless of sex[19].

Our analysis revealed that LLRS member orthopedic surgeons were more likely to have graduated from certain medical schools and residency programs, such as Yale School of Medicine (4), and Cleveland Clinic Foundation and University of California (San Francisco). Many LLRS members pursued pediatric or trauma fellowships, rather than limb lengthening and reconstruction/deformity correction specifically. The authors speculate that this may be due to the non-accredited nature of limb lengthening and reconstruction/deformity correction programs. This emphasizes the potential benefits of establishing accreditation, encouraging and enabling surgeons interested in such specialized fellowship training[20].

A call for accreditation in limb lengthening and reconstruction/deformity correction fellowships could facilitate increased participation of surgeons interested in this specific field[20]. Moreover, involving teaching centers specializing in limb lengthening and reconstruction/deformity correction fellowships in LLRS and AAOS initiatives could further

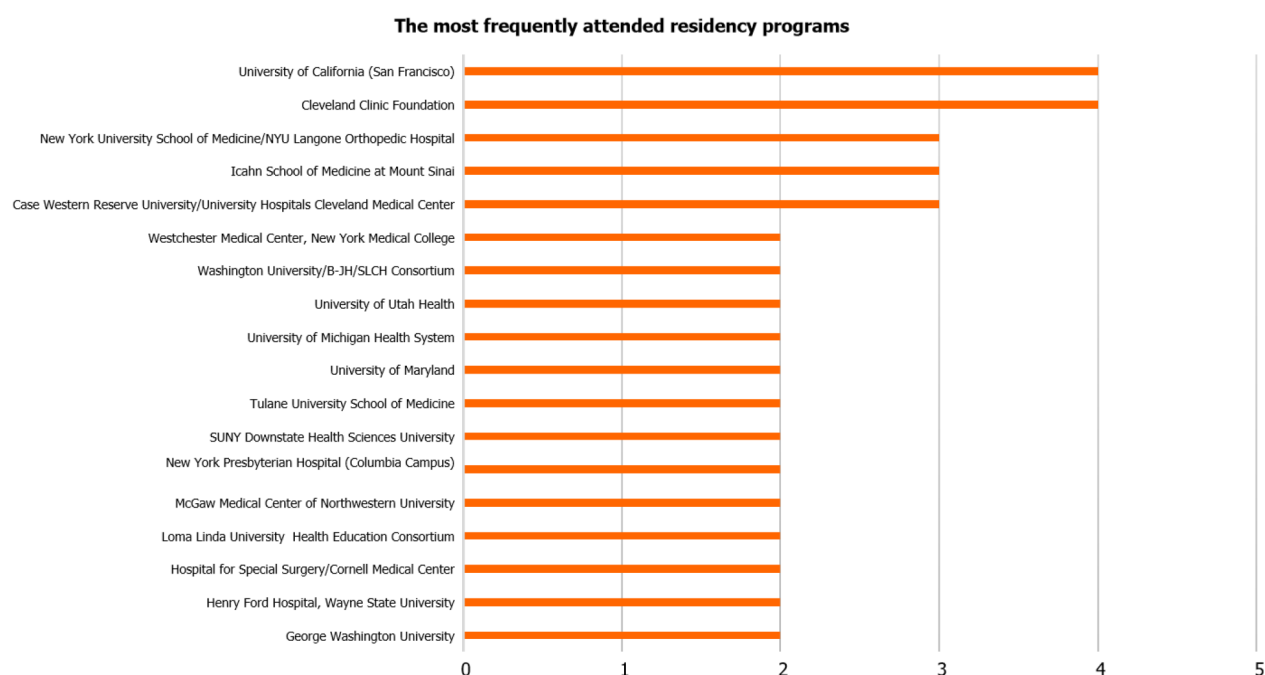


Figure 3 The most frequently attended residency programs.

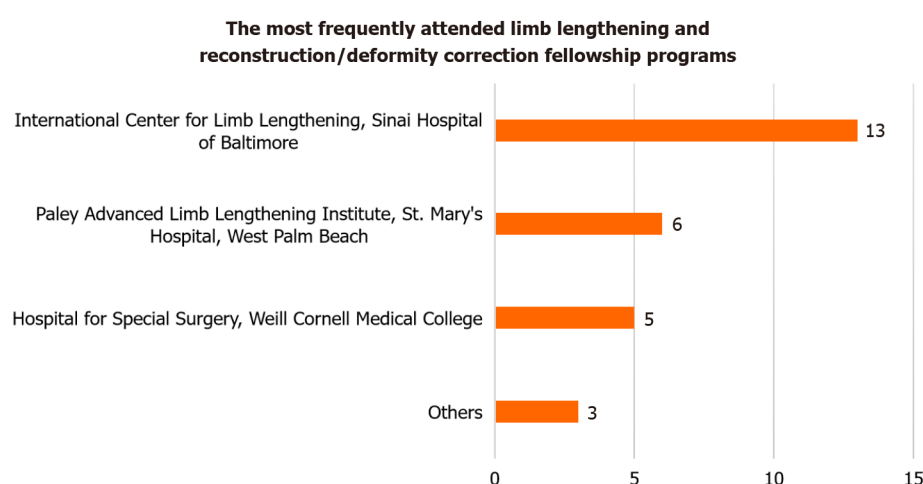


Figure 4 The most frequently attended fellowship programs.

advance the field. For instance, the ICLL at Sinai Hospital of Baltimore emerged as a leading producer of LLRS member orthopedic surgeons across the United States, despite Baltimore having being home to only two LLRS members.

It is important to address the geographical distribution of LLRS members. Our analysis reveals that 19 states in the United States had no LLRS member orthopedic surgeons at all. Ensuring the availability of LLRS member surgeons in areas with the lowest per capita representation, particularly in the New England and Middle Atlantic or Northeast regions, should be a notable consideration for future development.

To the best of our knowledge, this is the largest analysis of the LLRS, expounding upon the existing knowledge base in the field of limb lengthening and reconstruction by providing insights into the academic, leadership, demographic, and geographical distribution of its members. The findings herein can serve as a resource for aspiring orthopedic professionals and inform strategies for increasing diversity and equity, promoting equality and growth in leadership development, and advancing the field toward patient care optimization.

The novel findings of this study include the positive observation of a higher representation of women within LLRS compared to recent studies on orthopedic faculty and AAOS members. Additionally, the research emphasizes the prolific engagement of LLRS members in research, irrespective of their affiliation with academic or non-academic facilities. The identified medical schools and residency programs associated with LLRS surgeons provide new insights into potential pathways for specialized training. In terms of future directions, the study calls for addressing persistent gender disparities in leadership positions within LLRS, advocating for increased equity efforts.

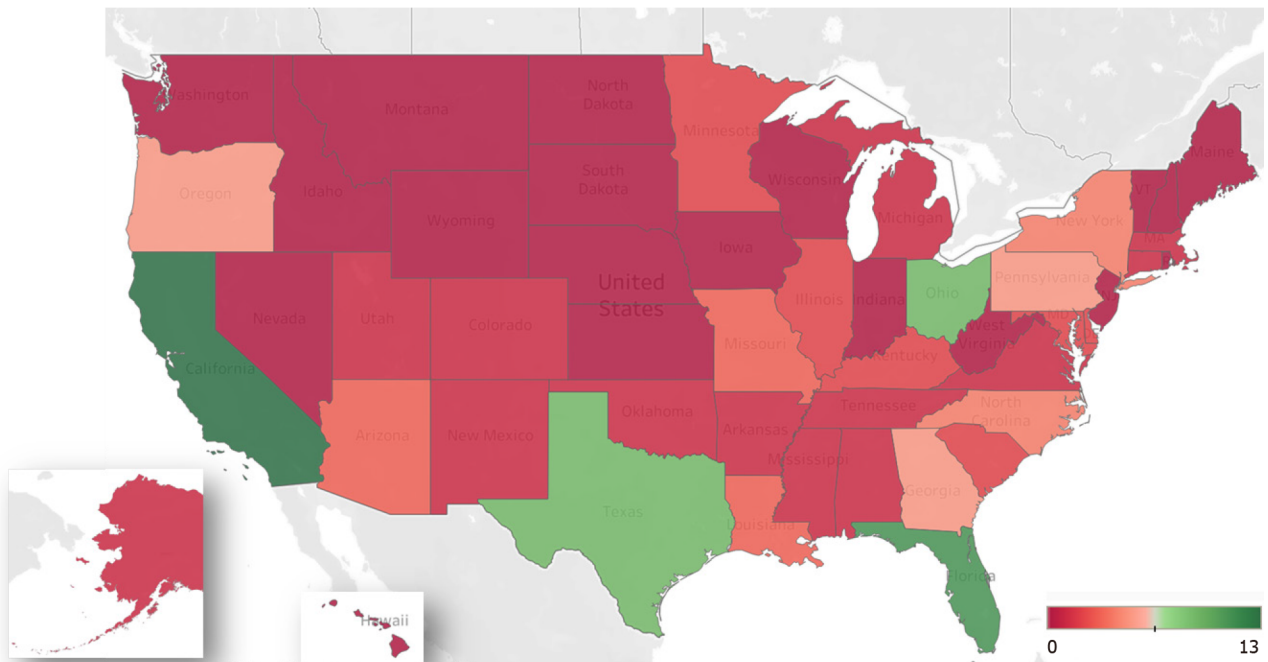


Figure 5 United States total distribution of Limb Lengthening and Reconstruction Society orthopedic surgeons.

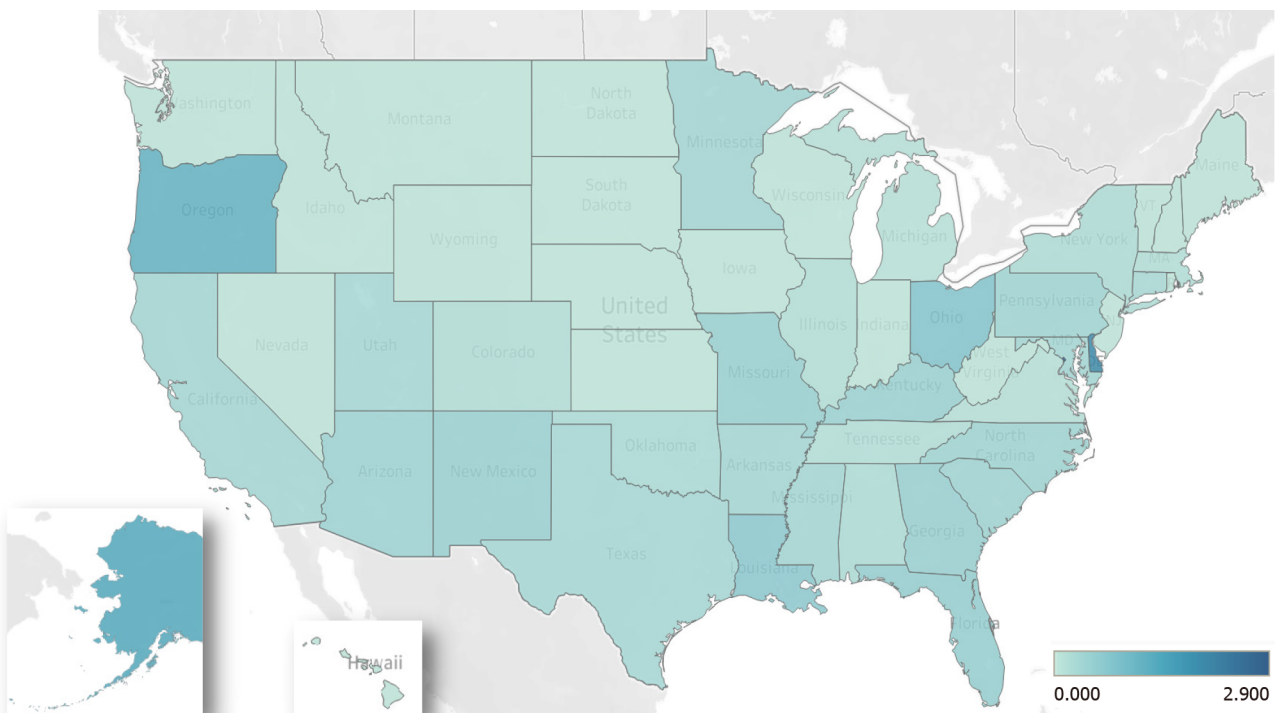


Figure 6 Per capita distribution of Limb Lengthening and Reconstruction Society orthopedic surgeons in the United States.

We do acknowledge certain limitations inherent to our study. Given the cross-sectional nature of the reporting, which represents the characteristics of LLRS members at the current time, we cannot comment retrospectively on the evolution of demographic and geographical diversity which constitutes the society's precedent progress. By design, we also relied on information obtained from websites, institutional biographies, and publicly accessible databases, which carry the innate possibility of containing inaccurate or outdated reporting, particularly in the application of the ethnicity definition method.

CONCLUSION

The LLRS is a specialized organization of orthopedic professionals for the advancement of limb lengthening and reconstruction. Its membership includes a favorably higher representation of women than recently reported in studies on orthopedic faculty and AAOS members. In general, LLRS members are prolifically engaged in research activity, regardless of academic or non-academic facility affiliation. Gender disparities do persist, however, in the attainment of leadership positions. The analysis also identified key medical schools and residency programs associated with LLRS orthopedic surgeons, emphasizing the potential benefits of accreditation and increased involvement of specialized centers. Geographical distribution highlights the need to address the lack of LLRS surgeons in certain regions. This study enhances the existing knowledge base in limb lengthening and reconstruction, providing valuable insights for various stakeholders in the field.

ARTICLE HIGHLIGHTS

Research background

This study delves into the demographic traits of Limb Lengthening and Reconstruction Society (LLRS) orthopedic surgeons in the United States, aiming to fill existing information gaps.

Research motivation

Motivated by the need to guide aspiring orthopedic professionals and promote diversity within LLRS, the research contributes valuable insights for organizational growth and inclusivity.

Research objectives

The study analyzes LLRS members' demographic, academic, and leadership attributes to inform aspiring professionals and support future research in the orthopedic field.

Research methods

Utilizing a cross-sectional approach, the study employs various metrics, including the Hirsch index, and applies the Mann-Whitney *U* test for specific comparisons.

Research results

The study reveals demographic trends among 101 orthopedic surgeons, emphasizing progress in gender diversity. It underscores the dedication of LLRS members and highlights the need to address geographic disparities for improved regional care access.

Research conclusions

Concluding that gender disparities persist in leadership roles; the study calls for increased equity efforts. It also emphasizes the need for strategic improvements in regional care access, aligning with the goal of enhancing global patient care.

Research perspectives

Future research should focus on mitigating gender disparities in LLRS leadership and improving the geographic distribution of members, ensuring equitable access to limb lengthening and reconstruction expertise across diverse regions.

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FOOTNOTES

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