TEACHING ANATOMY

Is Wikipedia a complete and accurate source for musculoskeletal anatomy?

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Abstract

Purpose Wikipedia is a popular online encyclopedia generating over 5.4 billion visits per month, and it is also a common resource for the general public and professionals for medical information. The goal of this study is to determine the accuracy and completeness of Wikipedia as a resource for musculoskeletal anatomy.

Methods The origin, insertion, innervation, and function of all muscles of the upper and lower extremities as detailed on Wikipedia was compared to the available corresponding information in Grant's Atlas of Anatomy (14th edition). Entries were scored for both accuracy and completeness. Descriptive statistics were calculated and associations between and within entries for accuracy and completeness were assessed by McNemar's tests. Information on Wikipedia's references was also collected.

Results Overall, data on Wikipedia was 97.6% complete and 98.8% accurate when compared to Grant's Atlas of Anatomy. 78.6% of all entries were fully complete and accurate, with 15.3% of entries containing one error and 6.1% containing two errors. There were no associations between or within entries' accuracy and completeness. Only 62% of references from Wikipedia included were from academic sources.

Conclusions Musculoskeletal anatomy entries on Wikipedia are imperfect; they have inaccurate and missing information. Furthermore, a considerable proportion of references cited in entries are from poorly identified sources. While Wikipedia is an easily accessible resource for a large number of people and much of the anatomic information is appropriate, it cannot be considered to be an equivalent resource when compared to anatomic texts.

Keywords Wikipedia · Anatomy · Musculoskeletal anatomy · Medical education · Online learning · Internet resources · Grant's anatomy

Introduction

The quality and veracity of available Internet-based medical information vary from peer-reviewed medical publications to publicly available websites created by non-medical professionals that do not require peer review. While scientific, peer-reviewed texts remain the gold standard for dissemination of medical knowledge, these sources are not readily accessible to the general public or easily accessed by mobile Internet searches due to their cost and requirement of institutional or individual subscriptions.

One of the most commonly used publicly available websites is Wikipedia. Wikipedia is an important medical resource to consider due to its proclivity in being a top search result for many queries, as well as it being the fifth most visited website in the world with over 5.4 billion visits per month [2]. The content within Wikipedia is user-generated and can be edited immediately by anyone. Wikipedia does employ a stringent process of community oversight and review, with all content required to be verifiable, reliable, and cited [24]. However, despite this community standard, information disseminated within Wikipedia is not held to the same standard of scientific review as a peer-reviewed publication.

Previous research has examined Wikipedia articles' content accuracy. In a 2005 study published in Nature, it was determined that on average Wikipedia science entries contained four inaccuracies while Encyclopedia Britannica

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(held as the gold-standard) had three. Many factual errors, omissions, and misleading statements were identified in both publications [10].

Specifically, in regards to medical information, both patients and medical professionals routinely utilize Wikipedia as a resource [17]. Additionally, medical learners have been shown to rely on websites such as Wikipedia for their knowledge [3, 14], with some researchers finding these websites to be appropriate for learning [21], while others questioning their appropriateness [6].

In the realm of anatomical content, the question of content accuracy has been previously explored, but not in any methodologically robust manner [23]. Therefore, the goal of this study was to determine whether Wikipedia entries for musculoskeletal anatomy are *accurate*, meaning all information included is factually correct, and *complete*, meaning that no relevant information is missing when compared to an established medical anatomy textbook. We hypothesized that there would be a difference in entry accuracy and completeness when comparing Wikipedia to Grant's Atlas of Anatomy.

Materials and methods

Four authors (DAL, SMA, AVC, JHK) documented the origin, insertion, innervation, and function of all muscles of the upper and lower extremities as published on Wikipedia (last searched on March 2018). Grant's Atlas of Anatomy (14th edition) [1] was utilized as the established anatomy textbook for comparison. The Wikipedia entries were compared to the corresponding Grant's entries with regards to accuracy and completeness. Additional data were collected from each Wikipedia entry examined, including the frequency and type of the listed references.

Definitions of accuracy and completeness were consistent with previously published articles comparing Wikipedia to the medical literature [9]. An accurate Wikipedia entry only includes information that is factually correct in comparison to the corresponding entry in Grant's. For example, if there were two points of origin for a given muscle listed in Wikipedia, that Wikipedia data would be considered accurate if both of those points of origin were similarly listed in Grant's. Conversely, the Wikipedia entry would be considered inaccurate if it listed a point of origin that differed from Grant's that was not accurate.

A complete Wikipedia entry contains all data points when compared to the corresponding entry in Grant's. For example, if there were two points of origin for a given muscle listed in Grant's, the Wikipedia entry would be considered complete if it listed both individual points of origin. It would be considered incomplete if it did not list one or both points of origin.

Each individual muscle was scored for accuracy and completeness for its origin, insertion, innervation, and function. Each component (origin, insertion, innervation, function) of each muscle was scored independently by two authors (SMA and DAL) and any discrepancies were adjudicated by the senior author (JMK). In cases where Wikipedia provided detailed information that went beyond the scope of Grant's, the primary reference was reviewed from the Wikipedia page to determine the accuracy of the information.

Table 1 represents an example calculation for accuracy and completeness for the flexor digitorum superficialis's origin. There were four unique origins listed in Grant's and three in Wikipedia. Two of the entries for origin in Wikipedia matched those in Grant's. The third, "parts of radius and ulna" was not felt to be specific enough to warrant a match to "coronoid process" and "superior half of the anterior body of the radius" in regards to completeness. The completeness score was 50% given the specific identification of two origins out of four listed in Grant's. However, since "parts of the radius and ulna" is not incorrect all three points of origin listed by Wikipedia were accurate, thus the 100% accuracy score.

The data for each muscle were simplified to a binary state (fully accurate: yes/no; fully complete: yes/no) and descriptive statistics were calculated on the completeness and accuracy of muscles' origin, insertion, innervation, function, and overall status. Associations between entries' overall accuracy and completeness were assessed by McNemar's test due to presumed dependence. Additional McNemar's tests were performed to assess associations between completeness and accuracy for each component (e.g. comparing origin completeness and origin accuracy), with post hoc Bonferroni corrections for multiple comparisons. Chi-Square tests were performed to see if there were any associations between components in terms of their completeness and

Table 1 Example of scoring system for completeness and accuracy

Muscle	Grant's	Wikipedia	Accuracy	Completeness
Flexor digitorum superficialis (origin)	1. Medial epicondyle 2. Ulnar collateral ligament 3. Coronoid process 4. Superior half of anterior body of radius	1. Ulnar collateral ligament 2. Medial epicondyle 3. Parts of radius and ulna	3/3 = 100%	2/4 = 50%*

*Coronoid process, superior half of anterior body of radius missing

accuracy (e.g. comparing origin completeness to insertion completeness), with post hoc Bonferroni corrections for multiple comparisons. Data were then analyzed as composite scores to account for muscles with multiple origins, insertions, innervations, and functions. McNemar's tests were performed again for these data in the same fashion as described above. For all statistical tests, significance was defined as $\alpha < 0.05$.

Results

One hundred and one unique muscles were identified for inclusion in this study, 50 upper extremity muscles and 51 lower extremity muscles. Three muscles had a missing entry in Grant's Atlas of Anatomy (palmaris brevis, extensor hallucis brevis, extensor digitorum brevis). All 101 muscles had a unique webpage on Wikipedia. Ninety-eight muscles were available for analysis.

78.6% (77/98) of Wikipedia entries were both fully accurate and fully complete for a muscle's origin, insertion, innervation, and function when compared to Grant's. For the 21 entries with errors, 15 (15.3%) had only one error and 6 (6.1%) contained two errors. A greater percentage of entries were either fully accurate (90/98, 91.8%) or fully complete (83/98, 84.7%), but not both. Three entries had both incomplete and inaccurate data. There was no association between entries being accurate and complete ($p = 0.167$).

Table 2 demonstrates the number of entries that were fully complete and accurate stratified by components. Origin, insertion, and innervation data were complete 96.9%, 100%, and 98.0%, respectively, while muscle function data were complete 89.8%. There were no associations between the completeness of any of the components (all $p > 0.05$). The accuracy of origin, insertion, innervation and function were 100%, 99%, 96.9% and 95.9%, respectively. These components also had no association between their accuracy (all $p > 0.05$). Furthermore, there were no associations between completeness and accuracy for any of the muscle components (all $p > 0.05$).

When we considered multiple components of origin, insertion, innervation and function, the data within Wikipedia were 97.6% complete and 98.8% accurate in total, which is a greater percentage then when these items were assessed in a binary manner. Table 3 demonstrates these proportions separated by origin, insertion, innervation, and function. Similar levels of completeness and accuracy were observed compared to the binary results with origin, insertion, and innervation data being the most complete and accurate, while function data was least. There are no statistically significant differences when comparing any of the percentages to each other (all $p > 0.05$).

On average, Wikipedia entries cited 4.8 references per entry. Academic references, such as medical textbooks and peer reviewer articles only comprised 62% of total references. Non-academic references were routinely cited and included YouTube videos, other websites without clearly identified sources, and non-functioning hyperlinks. Publicly available Gray's Anatomy (1918 Edition) [11] was the primary source of information in 74% of the Wikipedia entries.

Discussion

Wikipedia entries on musculoskeletal anatomy contained information that was 97.6% complete and 98.8% accurate when compared to Grant's. Despite this overall high concordance, only 78.6% (77/98) of entire Wikipedia entries were both fully accurate and complete, with the remaining entries tending to have one error regarding either accuracy or completeness. While these data demonstrate that musculoskeletal anatomy entries on Wikipedia are imperfect, much of the anatomic information is appropriate. Although Wikipedia cannot be considered to be an equivalent resource when compared to anatomic texts, these results do demonstrate the utility of the Wikipedia as a quick fact-finding resource for basic musculoskeletal anatomy. We, therefore, rejected our hypothesis.

Internet-based medical resources have rapidly expanded with increased public reliance on the Internet for the consumption of medical information. Wikipedia is no exception as the website has gained popularity amongst both patients and physicians as a medical resource [17], with published reports demonstrating that up to 35% of pharmacists and

Table 2 Number of complete and accurate entries

Component	No. of complete entries (%)	No. of accurate entries (%)
Origin	95/98 (96.9)	98/98 (100)
Insertion	98/98 (100)	97/98 (99.0)
Innervation	96/98 (98.0)	95/98 (96.9)
Function	88/98 (89.8)	94/98 (95.9)

Table 3 Number of complete and accurate data point

Component	No. of complete entries (%)	No. of accurate entries (%)
Origin	181/185 (97.8)	185/185 (100)
Insertion	120/120 (100)	120/121 (99.2)
Innervation	107/109 (98.2)	109/112 (97.3)
Function	214/226 (94.7)	227/230 (98.7)

70% of physicians utilize Wikipedia to look up medical information [8, 13].

There have been multiple attempts across several medical subspecialties to evaluate the content within Wikipedia and determine whether it is an appropriate resource for medical information. Azer et al. examined 47 Wikipedia entries on the cardiovascular system with regards to both accuracy and readability and reported that only 8.5% of articles were of "good" quality and that the average reading level of these articles were for college graduates, and thus not appropriate for either the public (too high a level) or a physician (too low a level). They concluded that Wikipedia should not be used as a medical resource [7]. Similar studies were performed for Wikipedia entries regarding both pulmonary and gastrointestinal pathophysiology which concluded that Wikipedia articles were confusing and difficult to read and thus not appropriate for public consumption [5, 6, 12].

Other studies in oncology have shared concerns regarding, readability, but did find entries to have similar accuracy and depth as professional resources [19]. Similarly, for information regarding mental disorders, authors found Wikipedia to have higher level content in regards to accuracy, breadth of coverage and referencing when compared to other websites, general encyclopedias, and a psychiatry textbook, but they also had concerns with readability of entries [20]. In contrast, other expert evaluators in oncology appreciated the usability of the Wikipedia entries and found their data to be "good" but inferior when compared to professional sources [16].

The most extensive research regarding the utility of Wikipedia as a medical resource has been undertaken with regards to information on pharmacology. Kraenbring et al. compared Wikipedia to standard textbooks of pharmacology concerning basic drug information and reported that Wikipedia was 99.7% accurate and 83.8% complete [15]. However, similar investigations comparing Wikipedia both to drug insert medication guides and to other online medical encyclopedias reported that Wikipedia was written for an audience with a substantially higher literacy level than the average United States consumer and, furthermore, was less complete and accurate than drug insert guides and other online encyclopedias [9, 20].

In regards to anatomy specifically, Vilensky and Steenberg assessed the quality of the Wikipedia anatomic entries in a non-standardized fashion [23]. They found the information to be generally accurate, but not appropriate for graduate level learners. Our findings build on this initial work by systematically analyzing the accuracy and completeness of the musculoskeletal anatomic entries on Wikipedia, thereby providing a more robust foundation on which to base our conclusions.

The literature demonstrates variability with regards to the accuracy and completeness of Wikipedia medical entries, and thus a lack of clarity regarding their appropriateness to be utilized as a medical resource. The purpose of this study was to perform a similar examination on musculoskeletal anatomy as published on Wikipedia. The basic anatomy of the musculoskeletal system is at the

Fig. 1 Screenshot of the Wikipedia entry for the Flexor Digitorum Superficialis muscle. This demonstrates how in the upper right corner of the screen is easily accessible information pertaining to a muscle's origin, insertion, innervation, and action

core of orthopedic education. By analyzing Wikipedia's content we asked the most fundamental question within the orthopaedic speciality as it pertains to this popular and ubiquitous online resource. While other researchers have had a concern about readability of entries, this is of minimal concern for this topic as basic anatomical information is frequently listed in a table format in the right-hand column of Wikipedia entries (Fig. 1).

A further question that emanates from this work is how commonly do patients and learners consult Wikipedia and other Internet-based resources for information, and to what degree in comparison to more peer-reviewed resources. Furthermore, our findings bring into question the causes and consequences of such behavior for both patients and learners. While our data do not answer these questions, these are the logical next steps to further research this topic. We can hypothesize that such behavior emanates from the convenience as Wikipedia results are frequently the top result for most anatomical related Internet queries. Additionally, most anatomic textbooks and reference articles, while available on-line, exist behind paywalls that do not allow for quick and easy access via mobile searches. There may also be a certain trust that learners and patients place in crowd-sourced material, believing that if it were false another user would have already corrected it.

Based on our results, continued reliance on crowd-sourced material mostly likely would not lead learners or patients astray at a general level; however, there is a risk for more detailed information, which may be published in academic journals, to be missing from Wikipedia entries. The consequence of not gaining this higher level of detail for medical education learning is not clear, but concerning for a continued degradation in the knowledge base.

One way anatomic educators could work around this conundrum is by creating online content that is easily searchable and accessible that can provide a more controlled source of referenced anatomic knowledge, such as has been shown by Ozer et al. [18]. Furthermore, since Wikipedia searches will undoubtedly continue, and the general population has too many hindrances to access paywalled material, another approach would be to improve Wikipedia's anatomical entries. Previous research has demonstrated that medical learners can be used to edit Wikipedia entries on health topics such as medications [4], and it has been hypothesized such activities could enhance student learning [22]. Therefore, such tasks could be incorporated into anatomical courses to both improve Wikipedia entries as well as increase learner knowledge.

The primary limitation of this study is that Wikipedia entries can be updated at any given time. This data represents a snapshot in time of the overall accuracy and completeness of information on musculoskeletal anatomy in Wikipedia. However, given the strict process of oversite within the Wikipedia community, it is unlikely that major changes would occur to significantly decrease the overall accuracy or completeness of Wikipedia. Rather, it is more likely that this data will only improve as community editors continue to update the data on each individual entry.

A second limitation of this study is that it compares data on Wikipedia only to Grant's Atlas of Anatomy. While Grant's is a well-respected anatomic atlas, it does not contain all current knowledge with regards to musculoskeletal anatomy. For orthopedic trainees and surgeons, advanced anatomic principles may require a level of detail that is not represented in either Wikipedia or Grant's or perhaps both resources. For example, some points encountered on Wikipedia with regards to origin, insertion, innervation, and function of a given muscle were known to be accurate by the authors, despite the fact that they were not found in Grant's. These data points were not counted as inaccurate even though they were not mentioned in Grant's. This suggests that, in some instances, Wikipedia may represent a more accurate and complete source for musculoskeletal anatomy than Grant's.

Conclusion

Wikipedia is a relatively complete and accurate source of basic musculoskeletal anatomy. While it should not replace the gold standard of peer-reviewed textbooks and journal articles, Wikipedia can be considered a good option for convenient reference for basic musculoskeletal anatomy.

Compliance with ethical standards

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