Network Analysis of Sport-related Concussion Research During the Past Decade (2010-2019)

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Acknowledgements: The authors have no competing interests to disclose. This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Context: There has been substantial growth over the past decade in sport-related concussion (SRC) research, yet no research to date has synthesized developments over this critical time period. Objective: to apply a network analysis approach to evaluate trends in the sport-related concussion (SRC) literature using a comprehensive search of original, peer-reviewed research articles involving human participants published between January 1, 2010 and December 31, 2019. Design: Narrative review. Main Outcome Measures: Bibliometric maps were derived from a comprehensive search of all published, peer-reviewed SRC articles on the Web of Science database. A clustering algorithm was used to evaluate associations among journals, organizations/institutions, authors, and keywords. The online search yielded 6,130 articles, 528 journals, 7,598 authors, 1,966 organizations, and 3,293 keywords. Results: The analysis supported five thematic clusters of journals: 1. Biomechanics/Sports medicine (n=15), 2. Pediatrics/Rehabilitation (n=15), 3. Neurotrauma/Neurology/Neurosurgery (n=11), 4. General Sports Medicine (n=11), 5. Neuropsychology (n=7). The analysis identified four organizational clusters with hub institutions: 1. University of North Carolina (n=19), 2. University of Toronto (n=19), 3. University of Michigan (n=11), 4. University of Pittsburgh (n=10). Network analysis revealed 8 clusters for SRC keywords, each with a central topic area: 1. Epidemiology (n=14), 2. Rehabilitation (n=12), 3. Biomechanics (n=11), 4. Imaging (n=10), 5. Assessment (n=9), 6. Mental health/Chronic Traumatic Encephalopathy (n=9), 7. Neurocognition (n=8), 8. Symptoms/impairments (n=5). Conclusions: The findings suggest that during the past decade SRC research has: 1) been published primarily in sports medicine, pediatric, and neuro-focused...
journals, 2) involved a select group of researchers from several key institutions, and 3) focused on new topic areas including treatment/rehabilitation and mental health.

Keywords: concussion, mild traumatic brain injury, rehabilitation, network analysis

Key points:

- The current findings represent the first network analysis of SRC research and suggest that during the past decade SRC research has been published primarily in sports medicine, pediatric, and neuro-focused journals.

- The current findings also suggest that SRC research focused on epidemiology, assessment, and return-to-play, as well as emerging areas of focus including rehabilitation and mental health.

- This study also highlights the benefits of using network analysis of SRC research to identify appropriate journals for article submissions, potential authors/institutions with whom to collaborate, and topics reflecting the direction the field is headed.
Introduction

Sport-related concussion continues to be a significant health concern affecting millions of athletes of all ages and levels, resulting in an estimated economic burden up to 17 billion dollars annually. This heterogeneous injury involves myriad signs, symptoms, and impairments, and although many athletes recover within a few weeks,¹ some take months or longer.² Given the large number of affected athletes and burden of this injury the field of SRC research has experienced tremendous growth during the past decade. In fact, a search of the term “sport-related concussion” in PubMed on January 24, 2020 yielded 1,822 peer-reviewed articles during the previous ten years. This work has enhanced our empirical and clinical knowledge of SRC in areas such as epidemiology, identification, assessment, recovery, and rehabilitation.³ However, researchers have yet to empirically synthesize developments and trends in SRC research during this period of rapid growth.

Research and clinical practice in concussion have evolved substantially since the late 1990s and early 2000s when literature emphasized SRC identification with a focus on grading scales, symptoms, and the role of loss of consciousness (LOC).⁴ As the field evolved from 2005-2010, the focus shifted to biomechanics, assessments of balance and cognitive performance, age and gender differences, recovery time, rest-based intervention and consensus statements designed to inform clinical care.⁵ More recently, SRC research has evolved to include ocular and vestibular assessments, advanced neuroimaging, fluid biomarkers, clinical subtypes or profiles, and rehabilitation.³,⁶,⁷ During the past decade, the paradigm of prescribed rest as the primary or sole management strategy for SRC was challenged by empirical evidence that supported more active approaches.⁸ The field has also begun to shift towards earlier, more active interventions that target specific symptoms and impairments.³ Empirical evidence has provided the basis for
these theoretical and clinical paradigm shifts and will continue to do so moving forward. However, the field of SRC research has lacked introspective analyses of past research trends to help guide future paradigms and approaches to clinical care. An empirical analysis of trends in SRC research during the past decade could inform future lines of inquiry and areas of clinical advancement.

Network analysis provides a useful tool to objectively assess the bibliographic trends of a scientific field. Based on the outcome of interest (e.g., journals, authors, institutions, etc.) network analysis produces an interconnected bibliometric map based on associations among outcomes. Given the rapid growth in SRC research over the previous 10 years, application of this method could provide a greater understanding of recent trends that may otherwise go unnoticed, including key research institutions, authors, and journals. This information could inform a foundational basis for future studies and collaboration.

The purpose of this study was to evaluate trends in the SRC literature using network analysis based on a comprehensive search of original, peer-reviewed research articles involving human participants published between January 1, 2010 and December 31, 2019. Specifically, we use network analysis to evaluate associations in the following areas: 1) peer-reviewed journals, 2) authors, 3) organizations/institutions, and 4) relevant keywords.

Methods

Articles were identified in the Web of Science Core Collection using key terms to encompass all forms of SRC (e.g., concussion, sport-related concussion, cerebral concussion, etc.) or mTBI (e.g., mild traumatic brain injury, mild brain injury, mild TBI, etc.) from 2010 to 2019 using human subjects. The search was conducted on December 15, 2019. Delimiting the search to the previous decade was chosen to focus on recent trends in SRC research. The search
was further refined to original articles, reducing the total number to 6,130 from 10,086. All bibliometric data, including title, authors, organizations, abstract, keywords, and bibliography, were imported into network analysis software (VOSviewer). Detailed mathematical description of the software and how it applies a variant of a multidimensional scaling algorithm can be found here. Search terms and their variants were removed from the analysis. Clusters (i.e., a group of interconnected nodes) were derived for each map using a resolution of 1.0, attraction of 2, repulsion of 1, minimum cluster size of 5, and resolution of 2. Clusters were subjectively named based on overarching themes of the individual cluster group. When interpreting the maps, connecting lines indicate an association between those nodes. Higher numbers of lines indicate more dense connections between the given node and its connecting nodes. Similarly, closer proximity between two nodes indicates a stronger association than two nodes at a further distance. Central location of a node indicates a higher number of connections, whereas more distal locations indicate a lesser number of connections.

The online search yielded 6,130 articles, 528 journals, 7,598 authors, 1,966 organizations, and 3,293 keywords. Citation analyses, or assessing the number of times journals/authors/organizations cite each other, were conducted to analyze journals, authors and organizations with specific minimum inclusion criteria: 5 publications for journals, 10 publications for authors, and 5 publications for organizations. Outcomes for each analysis included: number of articles, citations, total link strength, and clusters. For author and organization cluster reporting, the hub, or most highly interconnected individual author/organization, are reported as the cluster name. To analyze the top author keywords in concussion research, a co-occurrence analysis (i.e., assessing the number of articles in which multiple keywords occur together) was conducted with co-occurrence minimum of 10 for
inclusion. Variants of the search terms and populations were removed from analysis in order to investigate the key topics that have been assessed. Outcomes for keyword analysis are occurrences, total link strength, and clusters. The top 10 (ordered by most SRC publications within the study period) were also analyzed for journals, authors, organizations, and keywords using full counting.

Results

Table 1 presents number of publications, citations, and total link strength for the top 10 journals, organizations, and authors, as well as number of occurrences, citations, and total link strength for the top keywords from 2010-2019. The top 10 journals, organizations, and authors accounted for 48.1%, 34.1%, and 20.3% of total SRC publications for each respective category (journals n=59, organizations n=50, authors n=148). The top 10 keywords from 2010-2019 accounted for 32.3% of the total occurrences (n=78). Table 2 presents top 5 journals per cluster.

Network analysis revealed five journal clusters (categories) for SRC research (Figure 1): 1. Biomechanics/Sports medicine (n=15), 2. Pediatrics/Rehabilitation (n=15), 3. “Neuro-focused” (e.g., neurology, neurotrauma, neurosurgery) (n=11), 4. General Sports Medicine (n=11), 5. Neuropsychology (n=7). For institutions that publish SRC research, four clusters were identified (Figure 1b): 1. University of North Carolina (n=19), 2. University of Toronto (n=19), 3. University of Michigan (n=11), 4. University of Pittsburgh (n=10). For authors that publish SRC research, seven clusters were identified (Figure 1c): 1. Kontos (n=32), 2. Iverson (n=27), 3. McCrea (n=27), 4. Broglio (n=25), 5. Kerr (n=16), 6. Kroshus (n=14), 7. Guskiewicz (n=7).

Network analysis revealed eight keyword clusters for SRC research published from 2010-2019 (Figure 1d): 1. Epidemiology (n=14), 2. Rehabilitation (n=12), 3. Biomechanics (n=11), 4.
Discussion

The current study is the first to employ network analysis to evaluate trends in SRC literature among peer-reviewed journals, institutions, authors, and keywords. The results demonstrate that SRC research has been published primarily in sports medicine, and secondarily in pediatric and “neuro-focused” (i.e. combined neurology, neurosurgery, neurotrauma) journals. Four key, highly interconnected institutions – University of North Carolina, University of Toronto, University of Pittsburgh and University of Michigan – were identified that disseminate a disproportionate amount of SRC research (Figure 1b). Seven author clusters were also identified, with many of the author hubs located at the key institutions (Figure 1c). Eight keyword clusters were identified (Figure 1d), suggesting that epidemiology, assessment evaluation and return-to-play remain central themes with rehabilitation and mental health concerns emerging as newer focus areas.

Journals

Given that the overarching topic of the current analysis was concussion in sport, it was not surprising that sports medicine journals such as Journal of Athletic Training, American Journal of Sports Medicine, Clinical Journal of Sports Medicine, and British Journal of Sports Medicine, are primary outlets for SRC research (Tables 1 and 2). The largest journal cluster (n=15) was Biomechanics/Sports Medicine. As motion analysis and engineering technology has progressed over the past decade, this technology has been applied to SRC research to investigate topics such as the role of sub-concussive impacts, a force threshold for sustaining a SRC, sex
differences in neck and head control,\textsuperscript{14, 15} optimizing helmets for SRC prevention and identification.\textsuperscript{16} Rehabilitation/Pediatrics was tied for the largest cluster (n=15), with the most peer-reviewed publications during the study period (478; 19\% more than the next highest cluster). This body of research consists of risk factor identification for prolonged recovery and/or persistent post-SRC symptoms, like initial symptom burden, pre-injury mood disorders, personal or family history of migraine, vision and/or vestibular dysfunction pre- or post-injury.\textsuperscript{3, 17, 18} This research provides an important contribution to clinical understanding of SRC, as clinician knowledge about pre-existing risk factors can help guide management and intervention strategies. Additional management strategies and safe return-to-play and/or return-to-school guidelines were also a primary focus of this research cluster, reflecting the emphasis on pediatrics.\textsuperscript{19-21}

The third largest cluster was “Neuro-focus”, which focused on an enhanced clinical understanding of SRC heterogeneity, treatment efficacy, and assessment of objective biomarkers (e.g., cerebral blood flow, magnetic resonance imaging, diffusion tensor imaging, and blood biomarkers; Tables 1 and 2).\textsuperscript{22, 23} Specifically, the classification of different SRC presentations into “profiles” or “sub-types” and development of tools to identify these different types of SRC were found within this cluster.\textsuperscript{8} The purpose of identifying SRC profiles is to provide a framework for interventions that target individual responses to SRC.\textsuperscript{24} General Sports Medicine was the fourth largest cluster and focused on validation and implementation of assessments such as balance/postural stability, gait, vestibular/ocular impairment, and neurocognitive tests for identification and prognostic utility. Sideline assessments such as the Sideline Concussion Assessment Tool (SCAT) or symptom reporting scales were also a focus of this cluster. The final journal cluster was Neuropsychology (n=7). A focus of this cluster is neurocognitive and
neuropsychological testing, as these measures are commonly used to inform clinical diagnosis.\textsuperscript{25} Another focus of this cluster is symptom reporting measures and their diagnostic and prognostic value to the clinician. Although the topic areas within this cluster are broad, the core of this cluster is research focused on improving the neuropsychologist’s assessment and management of SRC.

\textit{Institutions and Authors}

The present analysis revealed that a select group of key institutions and authors have acted as the primary SRC research hubs over the past decade (Table 1; Figures 2-3). The University of North Carolina has published SRC research in topic areas such as knowledge/attitude of SRC among players and healthcare professionals, biomechanics of head impacts, and balance assessments, among others, over the past decade.\textsuperscript{13, 27-29} Epidemiology has also been a focus of this group.\textsuperscript{30, 31} The University of Toronto has focused on the potential role of imaging and other diagnostic tools to identify concussion and persistent symptoms, as well as pediatric concussion.\textsuperscript{32, 33} The University of Pittsburgh was another hub (n=10) identified in this analysis. Research from the University of Pittsburgh has focused on a clinical profile approach to SRC management, risk factors, and vestibular/ocular assessment and impairment following the injury.\textsuperscript{6, 7, 34} This group has also focused on sex differences in presentation and recovery, clinical assessments, and predictor of prolonged recovery from SRC.\textsuperscript{35, 36} University of Michigan was the final hub (n=11) identified in this analysis, whose publication focused on the utility and efficacy of clinical assessments\textsuperscript{37} and the role of biomechanics/head impacts.\textsuperscript{38} Together, these institutions represent the most prolific hubs of SRC research over the previous decade.

\textit{Keywords}
As the largest cluster and top co-occurring keyword, our analysis suggested that epidemiology was a primary focus of SRC research over the past decade, with close associations to knowledge, education and prevention (Tables 1 and 2; Figure 1d). Rehabilitation was the second largest cluster, with three of the top 10 most co-occurring keywords (e.g., balance, rehabilitation, recovery; Table 1). The rehabilitation cluster was associated with keywords from research focused on balance assessments, gait, and physical activity, among others. In a similar line of research, the Biomechanics cluster included research on head impacts and acceleration. Imaging and assessment were the only two clusters not represented by a keyword in the top 10 most co-occurring keywords of the decade, which may be related to the broad nature of their associations (Figure 1d). The Imaging cluster encompassed research using different imaging modalities, such as magnetic resonance imaging, as well as research related to neuropsychology and cognition. The inclusion of neuropsychology/cognition in this cluster is likely related to neurocognitive metrics being the clinical assessment of choice during imaging. The assessment cluster was associated with research that used keywords like video and vision analysis, among others.

During the last decade, research on SRC has also emphasized the long-term effects of the injury, as evidenced by the mental health/chronic traumatic encephalopathy cluster including three of the top 10 keywords: return-to-play, post-concussion syndrome and chronic traumatic encephalopathy (Table 1). This cluster also included anxiety and depression, two mental health topics that are increasingly viewed as important areas of focus for SRC research. The co-occurrence of these keywords is possibly related to increased public concern over the association of SRC with the development of neurodegenerative diseases and/or mood disorders later in life. The neurocognition cluster included impact as a top 10 keyword, which may refer to the
commonly used computerized neurocognitive test (i.e., Immediate Post-concussion Assessment and Cognitive Testing [ImPACT]) or head impacts or impact exposure. Finally, the Symptoms/Impairments cluster contained typical impairments associated with the injury, such as vestibular, ocular motor, and neurocognitive impairments, as well as general symptoms.

Strengths and Limitations

The current study contributes to the broader concussion literature by describing the relationships between topic areas (i.e., journal clusters) and individual journals who often publish research on that topic. This study provides a useful resource for clinicians and researchers alike to identify the top peer-reviewed information sources on their topic of interest (Table 2). The keyword analysis (Table 1 and Figure 4) provides the key contribution to the literature in the present work, as it reveals the co-occurrences and can elucidate trends within this period of enormous growth for SRC publications. For example, “rehabilitation” being the 9th ranked keyword of the decade is a critical finding, in the authors’ opinion (Table 1). This result is important, given that ~15-20 years ago SRC was still predominantly viewed as a homogenous injury that required a “one size fits all” treatment approach. Thus, “rehabilitation” would likely not have been a central focus of research during that time period, as everyone with concussion was usually treated with the same approach. Researchers can build on the key findings of the past decade to initiate more informed therapeutic trials to enhance our understanding of the efficacy of certain rehabilitation strategies. In order to maximize the potential of the next decade, SRC researchers can use the foundational research presented in the current study to identify the most pertinent areas for future inquiry.

Another critical aspect of informing treatment practice is the mitigation of potential long-term effects of SRC, such as post-concussion syndrome or chronic traumatic encephalopathy.
Keyword analysis in the present study indicates a substantial interest in these long-term effects over the past decade (Table 1). Recovery was also a top keyword of the decade. The significant co-occurrence of these keywords is possibly related to the increased public concern over SRC history and the development of neurodegenerative diseases later in life. Potential long-term effects of concussion are another area of SRC research that can benefit from intervention studies to provide high quality evidence. The present study can be used by clinicians and researchers to encourage collaboration and inform future lines of research in this area, among others.

There are limitations of this type of analysis worth noting. The study is delimited to SRC research within the study time period (2010-2019), so the findings presented here do not reflect concussion research prior to the inclusion date or in other populations (i.e., military, accidents, assaults, etc.). Additionally, each cluster and keyword could not be covered exhaustively due to space constraints. Therefore, the summary of journal clusters and keywords is informed by subjective decision making by the authors based on the results of the analysis. The software used in the network analysis is limited to word detection and cannot detect capitalizations of words. As such, the keyword “impact” could be referring to a physical contact that may have resulted in a concussion or a popular computerized neurocognitive test (i.e., ImPACT). Given the close proximity of “impact” and “neurocognitive testing” in the network map (Figure 1d), the authors suspect it was the latter, but this assumption cannot be definitively determined. Another limitation involves the space constraints in the network maps that resulted in certain nodes not having a label.

**Conclusion**

Our understanding of the identification, assessment, and rehabilitation of SRC has grown considerably over the past decade. The current findings represent the first network analysis of
SRC research and suggest that during the past decade SRC research has: 1) been published primarily in sports medicine, pediatric, and neuro-focused journals, 2) involved several key institutions within a broad field, and 3) focused on epidemiology, assessment, and return-to-play, as well as emerging areas of focus including rehabilitation and mental health. This study also highlights the benefits of using network analysis of SRC research to identify appropriate journals for article submissions, potential authors/institutions with whom to collaborate, and topics reflecting the direction the field is headed.

Acknowledgements: The authors have no competing interests to disclose. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
Figure 1a. Network map of journals that published sport-related concussion research from 2010-2019. Five clusters were identified: 1. Biomechanics/Sports medicine (red), 2. Pediatrics/Rehabilitation (green), 3. Neurotrauma/Neurology/Neurosurgery (blue), 4. General Sports Medicine (yellow), 5. Neuropsychology (purple).

Figure 1b. Network map of organizations that published sport-related concussion research from 2010-2019. Four clusters were identified (named for the primary hub): 1. University of North Carolina (red), 2. University of Toronto (green), 3. University of Michigan (blue), 4. University of Pittsburgh (yellow).

Figure 1c. Network map of authors who published sport-related concussion research from 2010-2019. Seven clusters were identified (named for the primary hub): 1. Kontos (red), 2. Iverson (green), 3. McCrea (blue), 4. Broglio (yellow), 5. Kerr (purple), 6. Kroshus (light blue), 7. Guskiewicz (orange).

Figure 1d. Network map of keywords used in sport-related concussion publications in peer-reviewed journals from 2010-2019. Eight clusters were identified 1. Epidemiology (red), 2. Rehabilitation (green), 3. Biomechanics (navy blue), 4. Imaging (yellow), 5. Assessment (purple), 6. Mental health/Chronic Traumatic Encephalopathy (light blue), 7. Neurocognition (orange), 8. Symptoms/impairments (brown).
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| Articles | Citations | Link Strength |
|----------|-----------|---------------|
| Journal of Neurotrauma | 145 | 2906 | 1445 |
| Journal of Athletic Training | 132 | 2530 | 1701 |
| Brain Injury | 121 | 1397 | 1125 |
| American Journal of Sports Medicine | 115 | 4763 | 2516 |
| Clinical Journal of Sports Medicine | 112 | 2250 | 1428 |
| British Journal of Sports Medicine | 87 | 3426 | 1472 |
| Journal of Science and Medicine in Sport | 60 | 591 | 455 |
| Journal of Head Trauma Rehabilitation | 46 | 743 | 582 |
| Frontiers in Neurology | 44 | 204 | 474 |
| Archives of Clinical Neuropsychology | 43 | 692 | 594 |
| University of North Carolina | 155 | 3503 | 4181 |
| University of Toronto | 135 | 1790 | 2049 |
| University of Pittsburgh | 108 | 2975 | 3254 |
| University of Michigan | 101 | 2190 | 2646 |
| University of Calgary | 95 | 1587 | 2446 |
| University of Washington | 88 | 1268 | 2232 |
| Harvard Medical School | 83 | 441 | 1961 |
| Harvard University | 81 | 2699 | 3068 |
| Boston Children's Hospital | 74 | 1269 | 2935 |
| Medical College of Wisconsin | 72 | 1426 | 2478 |
| Guskiewicz | 76 | 2997 | 3460 |
| Kerr | 68 | 1245 | 2336 |
| Meehan/Broglio (tie) | 64 | 1779/1786 | 2420/2804 |
| Kontos | 57 | 1805 | 2569 |
| Covassin | 56 | 1629 | 2291 |
| McCrea | 55 | 1398 | 2562 |
| Mihalik | 53 | 1020 | 1859 |
| Marshall | 52 | 1437 | 1992 |
| Comstock | 51 | 1761 | 1795 |
| Collins | 46 | 2030 | 2460 |

| Occurrences | Avg. Citations | Link Strength |
|-------------|----------------|---------------|
| Epidemiology | 82 | 18.9 | 25 |
| Impact | 73 | 19.3 | 53 |
| Return-to-play | 70 | 20.5 | 46 |
| Biomechanics | 55 | 17.9 | 25 |
| Chronic traumatic encephalopathy | 53 | 17.7 | 19 |
| Balance | 51 | 12.8 | 60 |
| Symptoms | 50 | 33.4 | 52 |
| Post-concussion syndrome | 49 | 26.8 | 37 |
| Rehabilitation | 46 | 13.6 | 42 |
| Recovery | 41 | 16.7 | 39 |
### Table 2. Top 5 journals within each cluster of sport-related concussion publications from 2010-2019

| Cluster                             | Journals                                                                 | Publications | Citations | Total Link Strength |
|-------------------------------------|---------------------------------------------------------------------------|--------------|-----------|---------------------|
| **Biomechanics/Sports Medicine**    | British Journal of Sports Medicine                                       | 87           | 3426      | 1472                |
|                                     | Journal of Science and Medicine in Sport                                  | 60           | 591       | 455                 |
|                                     | Medicine & Science in Sports & Exercise                                   | 43           | 1163      | 761                 |
|                                     | Annals of Biomedical Engineering                                         | 29           | 756       | 347                 |
|                                     | Journal of Sport Rehabilitation                                          | 23           | 82        | 121                 |
| **Pediatrics/Rehabilitation**       | Clinical Journal of Sports Medicine                                      | 112          | 2250      | 1428                |
|                                     | Journal of Head Trauma Rehabilitation                                     | 46           | 743       | 582                 |
|                                     | Orthopedic Journal of Sports Medicine                                    | 42           | 276       | 329                 |
|                                     | Pediatrics                                                               | 42           | 2091      | 1017                |
|                                     | Physician and Sports Medicine                                            | 39           | 256       | 356                 |
| **Neuro-focus**                     | Journal of Neurotrauma                                                    | 145          | 2906      | 1445                |
|                                     | Frontiers in Neurology                                                    | 44           | 204       | 474                 |
|                                     | Journal of Neurosurgery-Pediatrics                                        | 33           | 602       | 542                 |
|                                     | Plos One                                                                 | 31           | 552       | 276                 |
|                                     | Neurosurgical Focus                                                      | 24           | 505       | 339                 |
| **General Sports Medicine**         | Journal of Athletic Training                                             | 132          | 2530      | 1701                |
|                                     | American Journal of Sports Medicine                                      | 115          | 4763      | 2516                |
|                                     | Sports Health                                                            | 36           | 246       | 359                 |
|                                     | International Journal of Athletic Therapy and Training                     | 23           | 22        | 143                 |
|                                     | Journal of Neurologic Sciences                                           | 14           | 501       | 221                 |
| **Neuro-psychology**                | Brain Injury                                                             | 121          | 1397      | 1125                |
|                                     | Archives of Clinical Neuropsychology                                      | 43           | 692       | 594                 |
|                                     | Journal of International Neuropsychology Society                          | 28           | 605       | 417                 |
|                                     | Applied Neuropsychology-Child                                            | 26           | 149       | 311                 |
|                                     | Journal of Clinical and Experimental Neuropsychology                      | 25           | 291       | 199                 |
Figure 1b.
