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Highly Cited Canada Articles in Science Citation Index Expanded: A Bibliometric Analysis

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Abstract

The characteristics of the highly cited Canada articles in Science Citation Index Expanded from 1900 to 2011 were revealed. Articles that have been cited at least 100 times since publication to 2011 were assessed regarding their distribution in indexed journals and categories of the Web of Science. The citation lives of the top articles depending on citations in publication year, recent year, and years after publications were investigated for the impact history of articles. A new indicator, *Y*-index, was successfully applied to evaluate publication characteristics of Canada authors and institutions. University of Toronto was the most productive institution. The top three most productive categories of the Web of Science were biochemistry and molecular biology, multidisciplinary sciences, and neurosciences. *Journal of Biological Chemistry* and *Nature* hosted the most highly cited Canada articles. In addition, the *Y*-index was applied to evaluate the publication character of authors and institutions.

Key words: Scientometrics; Web of science; Y-index, Classic articles; Country

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INTRODUCTION

In recent years, bibliometric method as a common research tool has been widely used to measure the scientific performance of countries including Argentina, India, South Africa (Huffman et al., 2012), India (Gupta & Bala, 2011), Australia, Canada, Germany, the Netherlands, the United Kingdom, the United States (Glanville et al., 2011), Chile (George-Nascimento, 2010), Czech Republic (Vanecek et al., 2010), Turkey (Ergul et al., 2010), Spain (Alvarez & Anegon, 2009), Italy (Abramo et al., 2009), Austria, and Switzerland (Schreiber & Kindler, 2005). It is accepted that highly cited articles were considered as "classic citations" (Garfield, 1987). Highly cited articles have also been applied to reveal the recognition of scientific advancement and to give a historic perspective on the scientific progress (Baltussen & Kindler, 2004; Ohba et al., 2007). Classic articles are research works which have grand citation history, and have great impacts on their field (van den Broek, 1947; Garfield, 1976). The term of highly cited articles was also reported for journal citation studies (Garfield, 1974), clinical research (Ioannidis, 2005), and research works in the Science Citation Index Expanded (Ho, 2012). Highly-cited articles nevertheless provide an interesting and useful insight into which authors, articles and topics are influencing the research profession over time (Smith, 2008). Various studies have attempted to identify and analyze the highly cited articles in for example, fields of medical (Dubin et al., 1993; Gheiti et al., 2012), environmental and occupational health (Smith, 2009), water resources (Chuang et al., 2011), chemical engineering (Ho, 2012; Chuang et al., 2012), and environmental sciences (Khan & Ho, 2012). Highly cited publications of a country were also studied such as the fields of radiation oncology, biology, and physics in German, psychiatry in Russia, as well as highly cited papers from India and China. Analyses usually covered the distribution of publication output, science disciplines, contributing institutions, collaboration (Jeenah & Pouris, 2008; Marshakova-Shaikevich, 2006), as well as policy implication (Uthman

& Uthman, 2007). In addition, the citation life cycles of most cited papers with significant influence were revealed to provide more detail citation information (Fu et al., 2012).

The purpose of this paper is to identify and analyze highly cited articles of Canada in the Science Citation Index Expanded (SCI-Expanded) database from 1900 to 2011. The analysis covers annual production, field performance, research emphases, top cited articles, contributing institutions and authors. Some newly developed indicators related to title words, author keywords, and *KeyWords Plus* were employed to provide additional insights. A new indicator, *Y*-index, was developed and used to evaluate contributions of individual authors' and institutions' publication performance and characters.

1. METHODOLOGY

1.1. Data Collection

The methodology used in this study was based on the Science Citation Index Expanded (SCI-Expanded) database of Web of Science from Thomson Reuters. According to Journal Citation Reports (JCR) of 2011, it indexes 8,336 journals with citation references across 176 Web of Science categories in science edition. All 1,382,586 documents in 22 document types from 1900 to 2011 with "Canada" in the address field were searched. In order to verify that 1,018,576 articles were published by Canada. Total 1,635 articles from 17 institutions, for example Canada France Hawaii Telescope Corp, USA; National Research Council Canada, USA; University of Canada, Mexico; Canada College, USA; La Cañada High School, USA; and Texasgulf Canada Ltd., USA were excluded because these items were searched but not from Canada. Thus total 1,016,941 articles were published by at least one author with Canada affiliation within the publication year from 1900 to 2011 based on SCI-EXPANDED (updated on 23 November 2012). Another filter, TC_{2011} was used to retrieve the articles. The total number of times article cited from its publication to the end of 2011 was recorded as TC_{2011} (Wang et al., 2010; Chuang et al., 2011). $TC_{2011} \geq 100$ selected the articles as the highly cited Canada articles. The advantage of this indicator was its invariance, not updating as time goes on (Fu et al., 2012). Likewise, C_{2011}, the total number of citations of an article in 2011 and C_0, the total number of citations of an article in its publication year were employed to characterize the highly cited Canada articles. The records were downloaded into spreadsheet software, and manipulated using Microsoft Excel 2007.

In the SCI-EXPANDED database, the corresponding author is designated as the "reprint" author; this study uses as the term "corresponding author". In a single author article where authorship is unspecified, the single author is both first author as and corresponding author. Similarly, in a single institutional article, the institution is classified as the first author institution as well as the corresponding author institution. In a multi-author article where authorship is unspecified, the first author is classified as the corresponding author. Affiliations in England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK) (Chiu & Ho, 2005). Affiliations in Federal Republic of Germany (Fed Rep Ger), German Democratic Republic (Ger Dem Rep), West Germany, East Germany, Bundes Republik, and Germany were reclassified as being from Germany. Affiliations in Czechoslovakia and Czech Republic were also reclassified as being from Czech Republic. Affiliations in Yugoslavia and Slovenia were also reclassified as being from Slovenia. Affiliations in USSR and Russia were also reclassified as being from Russia. Similarly, affiliations in Netherlands Antilles and Netherlands were reclassified as being from Netherlands; affiliations in Greenland and Denmark were reclassified as being from Denmark; and affiliations in Hong Kong before 1997 were included with China (Fu et al., 2012). Affiliations in Zaire were reclassified as being from Democratic Republic of the Congo. The contributions from institutions and countries were identified by the appearance of at least one author in the publications.

1.2 Indicators

Seven indicators based on the country, institution, and author were used: (a) "Canada independent article", if the researchers' affiliations were all from Canada; (b) "institution independent article", if the researchers' affiliations were from the same institution in Canada; (c) "internationally collaborative article", if the articles were coauthored by researchers from not only Canada buy also other countries; (d) "inter-institutionally collaborative article", if authors were from different institutions in Canada; (e) "single author article", if there was only one author in an article, (f) "first author article", if the first author was from the institution in Canada for analysis; and (g) "corresponding author article", if the corresponding author was from the institution in Canada for analysis. *TP*, *IP*, *CP*, *SP*, *FP*, and *RP* are the number of total articles, Canada independent articles or institution independent articles, internationally collaborative articles or inter-institutionally collaborative articles, single author articles, first author articles, and corresponding author articles for institutions in Canada, respectively. The impact factor (IF_{2011}) of a journal was determined for each article as reported in the JCR 2011.

The author and the affiliation of the author, listed in one publication could be considered as the evidence of contribution (Coats, 2009). Both the number of authors on a paper and their positions in the byline need to be taken into account accurately when measuring author contribution (Mattsson et al., 2011). It has been accepted

conventionally that the most important positions are the first and the last, whom very often is the corresponding author (Zuckerman, 1968; Costas & Bordons, 2011; Mattsson et al., 2011). The first author has actually made the most contribution, and should receive a greater proportion of the credit (Reisenberg & Lundberg, 1990; Marušić et al., 2004). Accordingly, the non-first authors made less contribution (Shapiro et al., 1994). As important as the first author, another prominent authorship position is the corresponding author. The honorary authors including Nobel laureates were more likely to be listed last authors on scientific papers, rather than the first author (Zuckerman, 1968; Bates et al., 2004). The first author is commonly contributed the most, but the corresponding author obviously increases the author's credit for contributions to the study (Bhandari et al., 2004). Corresponding author was the one who contributed the most to the initial conception and supervision (Wren et al., 2007). Straight counting that accredits only the first or the corresponding author or fractional counting that accredits each collaborator with partial and weighted credit might be the better choices (Huang et al., 2011). *Y*-index (*j*, *h*) was developed to evaluate Canadian institutions and authors. *Y*-index provides a single index to identify publication characteristics related to the first author and corresponding author. This index is related to numbers of first author publications (*FP*) and corresponding author publications (*RP*), as defined (Ho, 2014):

$$j = FP + RP\ , \tag{1}$$

$$h = \tan^{-1}\left(\frac{RP}{FP}\right). \tag{2}$$

An author, institution, or country with a higher *j* indicates more articles as the first or corresponding author, playing the leadership role. *h*, differentiates the nature of the leadership role. When $h > 0.7854$, indicates more corresponding author articles and $h < 0.7854$, means more first author articles. When $h = 0$, j = the number of first author articles and $h = \pi/2$, j = the number of corresponding author articles.

2. RESULTS AND DISCUSSION

2.1. Publication Year

The 31,351 highly cited Canadan articles ($TC_{2011} \geq 100$) were published in the last 92 years from 1920 to 2011. Figure 1 shows the distribution of these articles over the decades and their citations per publication (*CPP*). The publication outputs by decade increased sharply from 1960s to 1990s and dropped in the latest decade. It has been pointed out that the numbers of times cited for an article is highly correlated with the length of time since its publication. The recent articles need time to accumulate citations (Gisvold, 1999). Similar phenomena could also be found in the top-cited articles in chemical engineering (Ho, 2012a) and the independent research of China's top universities (Fu & Ho, 2013). The decade with the most articles was the 1990s which had 12,594 articles (40% of 31,351 articles), followed by the decade of the 2000s with 8,012 articles (26%), and the decade of the 1980s with 7,322 articles (23%). The five most productive years were in the period of 1996 to 2000, including 1997 (1,475 articles), 1996 (1,436 articles), 1999 (1,409 articles), 2000 (1,407 articles), and 1998 (1,380 articles). There were no highly cited Canada articles found in the decade of the 1950s and only nine articles were published in 1960s. There were also only 63 articles (0.20%) published before 1970, while 66% of the highly cited Canada articles appeared after 1980s. Past research showed that, with increasing years, a paper has an increasing chance of being forgotten (Picknett & Davis, 1999). As time passes, even "true classics" are gradually being cited less often because their substance has been absorbed by the current knowledge, by a phenomenon called "obliteration by incorporation" (Garfield, 1987). Moreover, the number of articles in SCI-Expanded increased in last 100 years from 119,306 articles in 1910s to 9,468,553 articles in 2000s. It was suggested that to cite the original paper is needed (Ho, 2004). To cite the original paper is not only respecting authors who presented a novel idea in research but also to read the original idea in detail of the work (Ho, 2010).

In particular, the decade of the 1920's with 11 articles had much higher *CPP* with 309 which can be attributed to the article "A study of the Tisdall method for the determination of blood serum calcium with a suggested modification" by Clark and Collip in 1925 with a TC_{2011} of 1,490 times. The most frequently cited article (TC_{2011} = 34,128) was titled "Density-functional thermochemistry. III. the role of exact exchange" (Becke, 1993) by Becke from Queens University of Canada in 1993. Collip and Backus from University of Alberta of Canada, published the earliest highly cited Canada articles "The effect of prolonged hyperpnoea on the carbon dioxide combining power of the plasma, the carbon dioxide tension of alveolar air and the excretion of acid and basic phosphate and ammonia by the kidney" (Collip & Backus, 1920) in 1920 (TC_{2011} = 102). The most recent highly cited Canada articles were all published in 2011 in *Astrophysical Journal Supplement Series* with titles related to "seven-year Wilkinson microwave anisotropy probe (WMAP) observations" including subtitles "Cosmological interpretation" (Komatsu et al., 2011) with a TC_{2011} of 731, "Power spectra and Wmap-derived parameters" (Larson et al., 2011) with a TC_{2011} of 165, and "Sky maps, systematic errors, and basic results" (Jarosik et al., 2011) with a TC_{2011} of 126. Komatsu from University of Texas Austin of the USA, Larson from Johns Hopkins University of the USA, and Jarosik from Princeton University of the USA were first and corresponding authors of these three articles.

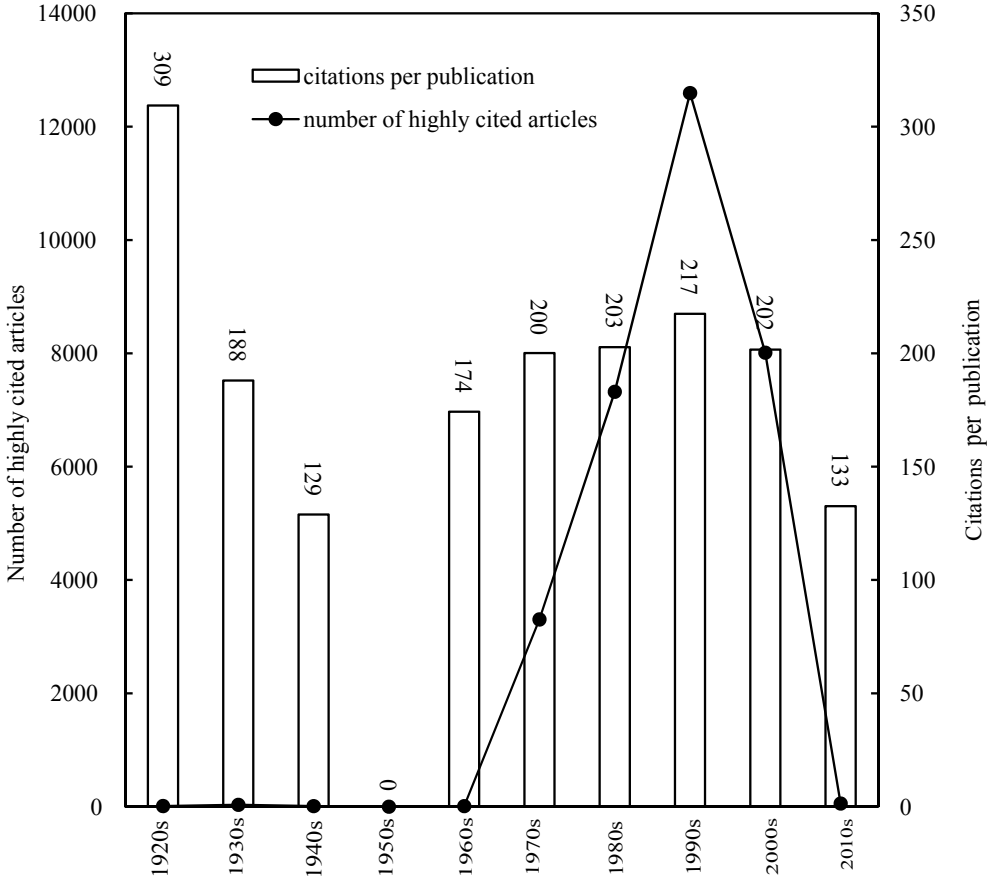

Figure 1
Number of Articles and Citations Per Publication by Decades

2.2 Journals and Web of Science Categories

The highly cited Canada articles were published by 2,452 journals across 174 Web of Science categories. Of these 2,425 journals, 914(37%) journals contained only one highly cited Canada article; 344(14%) journals contained two articles; 194(7.9%) journals contained three articles; and 127(5.2%) journals contained four articles. Twenty percent of the highly cited Canada articles were published in 11 journals including *Journal of Biological Chemistry* (IF_{2011} = 4.773) with 847(2.7%) articles, *Nature* (IF_{2011} = 36.28) with 838(2.7%) articles, *Proceedings of the National Academy of Sciences of the United States of America* (IF_{2011} = 9.681) with 775 (2.5%) articles, *Science* (IF_{2011} = 31.201) with 747(2.4%) articles, *New England Journal of Medicine* (IF_{2011} = 53.298) with 681(2.2%) articles, *Physical Review Letters* (IF_{2011} = 7.370) with 427(1.4%) articles, *Journal of the American Chemical Society* (IF_{2011} = 9.907) with 407 (1.3%) articles, *Circulation* (IF_{2011} = 14.739) with 368 (1.2%) articles, *Astrophysical Journal* (IF_{2011} = 6.024) with 352 (1.1%) articles, *Journal of Neuroscience* (IF_{2011} = 7.115) with 350(1.1%) articles, and *Lancet* (IF_{2011} = 38.278) with 318(1.0%) articles. It was noticed that leading journals attract the most-cited publications, which in turn maintain the high impact factor of these journals (Schein et al., 2000). However, highly cited articles still could be found in lower impact factor journals (Fu et al., 2012; Ho, 2012b). Highly cited Canada articles could also be found in journals with lower impact factors such as *Geoscience Canada* with IF_{2011} = 0.056, *Dialysis & Transplantation* with IF_{2011} = 0.131, and *IEICE Transactions on Information and Systems* with IF_{2011} = 0.178. Moreover, article "Accurate spin-dependent electron liquid correlation energies for local spin-density calculations—a critical analysis" (Vosko, 1980) ranked 3rd in TC_{2011} and 7th in C_{2011}, was published in *Canadian Journal of Physics* with IF_{2011} = 0.857.

Within the total 174 Web of Science categories in science edition the 11 top categories including biochemistry and molecular biology with3,400(11%) articles, multidisciplinary sciences with 2,440(7.8%) articles, neurosciences with 2,367(7.5%) articles, cell biology with 1,859(5.9%), general and internal medicine with 1,835(5.9%), oncology with 1,190 (3.8%), genetics and heredity with 1,113(3.6%), clinical neurology with 1,031(3.3%), immunology with 1,028(3.3%), astronomy and astrophysics with 865(2.8%), and physiology with

758(2.5%) articles, took the majority of the total highly cited Canada articles with a high percentage of 49%. Seventeen categories had less than 10 highly cited Canada articles including nursing, andrology, composites materials science, legal medicine, primary health care, construction and building technology, aerospace engineering, history and philosophy of science, integrative & complementary medicine, tropical medicine, logic, agricultural economics and policy, ocean engineering, characterization & testing materials science, and textiles materials science. Moreover, Canada had no highly cited articles in Web of Science categories of marine engineering and medical ethics.

2.3 Impact of Top Highly Cited Canada Articles

Impact of the top articles in total citations (TC_{2011}) (Chuang et al., 2011), citations in recent year (C_{2011}) (Ho, 2012a) has been reported. Impact of an article at publication year (C_0) was also studied in this study. The patterns of citation life cycles of top cited articles could provide the characteristics for the top articles (Aksnes, 2003). Total 14,245 highly cited Canadan articles (45% of 31,351 highly cited Canada articles) had no any citation in the publication year ($C_0 = 0$) and 18 articles (0.057%) had citations at least 100 times ($C_0 > 100$). Figure 2 shows the article life for the top nine most cited articles in their publication year ($C_0 \geq 120$). Five articles were published in 2000s, one in 1994, and three in 2011. Articles with higher citations at publication year (C_0) were likely to publish in recent years. Among top 18 articles with $C_0 > 100$, one article was published in 1994 and 1996 respectively and all others were published after 2000. One of reasons might be that number of journals in SCI database increased from 4,963 journals in 1997 to 8,336 journals in 2011. All articles in Figure2, had increasing citations after their publications then all showed decreased trends in following years. In highly cited Canada articles, "Seven-year *Wilkinson Microwave Anisotropy Probe* (WMAP) observations: cosmological interpretation" (Komatsu et al., 2011) published in *Astrophysical Journal Supplement Series* had the highest citations in its publication year ($C_0 = 731$) by 21 authors from USA, the UK, and Canada including M.R. Nolta from Canadian Institute for Theoretical Astrophysics and M. Halpern from University of British Columbia of Canada. However, it has been noticed that reviews with 350 citations in one year after publication was the highest citation (Garfield, 2002). In addition, "Effects of an angiotensin-converting-enzyme inhibitor, ramipril, on cardiovascular events in high-risk patients" (Yusuf et al., 2000) was the highest Canadan independent article with $C_0 = 217$.

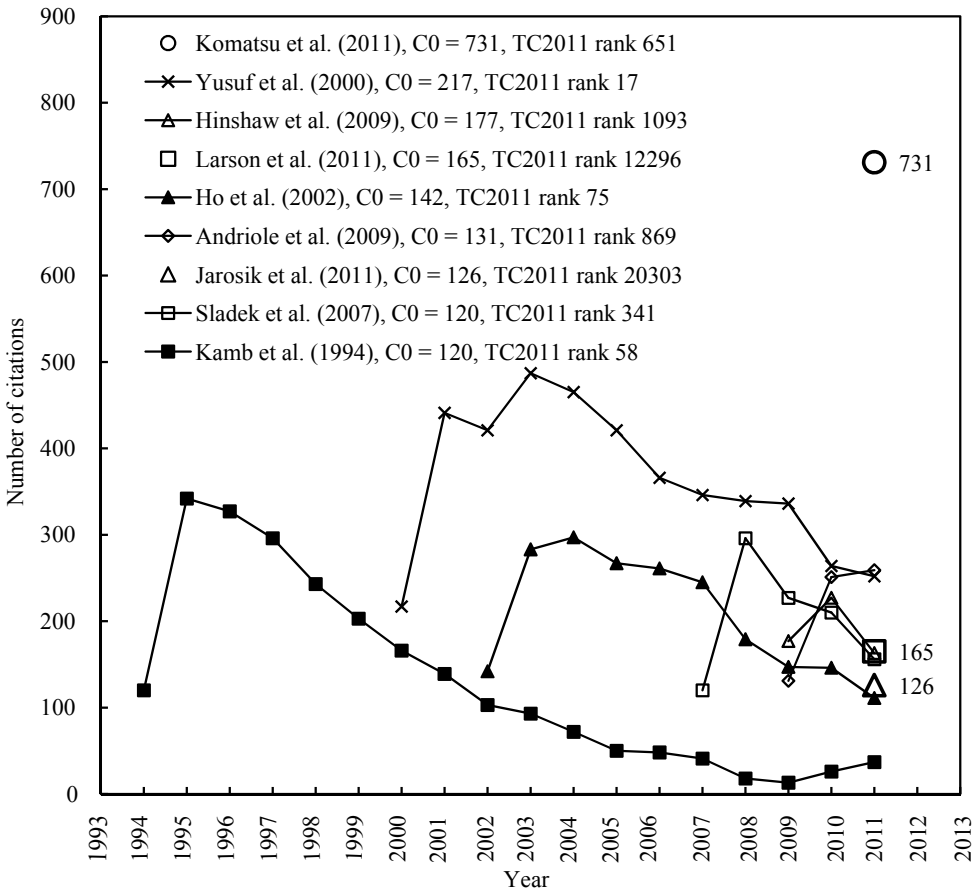

Figure 2
The Life of the Top Nine Most Frequently Cited Articles in Their Publication Year ($C_0 \geq 120$)

Impact of top cited articles in recent year was studied for the top-cited articles in chemical engineering (Ho 2012a; Khan & Ho, 2012). In recent year (2011), 2,711 highly cited Canada articles (8.6% of 31,351 highly cited Canada articles) had no any citation (C_{2011} = 0) and 14 articles (0.045%) had citations at least 500 times (C_{2011} > 500) including four article with C_{2011} > 1,000 and one article with C_{2011} > 4,000. The citation lives of the top ten articles (C_{2011} > 600) are shown in Figure 3. Most of these top cited articles had increased trend in citation after their publications. Earlier publications such as "Comparison of simple potential functions for simulating liquid water" by Jorgensen et al. (1983), "Prospect theory: analysis of decision under risk" by Kahneman and Tversky (1979), and "Accurate spin-dependent electron liquid correlation energies for local spin-density calculations: a critical analysis" by Vosko et al. (1980) had a long impact history since their publications. An sharply increasing trend of citations after publication year could be found for articles published in recent years including "New guidelines to evaluate the response to treatment in solid Tumors" by Therasse et al. (2000), "Distinctive image features from scale-invariant Keypoints" Lowe (2004), and "Radiotherapy plus concomitant and adjuvant temozolomide for glioblastoma" by and Stupp et al. (2005). The article entitled "Regression shrinkage and selection via the Lasso" by Tibshirani (1996) also had sharply increased trend of citations after its publication for eight years. Internationally collaborative article "*Crystallography & NMR system*: A new software suite for macromolecular structure determination" by Brünger et al. (1998) had the most sharply citation increased after its publication to a peak in 2004 then dropped to 668 times in 2011. The article "A new mixing of Hartree-Fock and local density-functional theories" by Becke (1993) was the most super cited article in 2011 with C_{2011} = 4,200. The internationally collaborative article published by Komatsu et al. in 2011 was not only the most frequently cited article with C_0 = 731 citations, but also the super cited article ranked 6th in C_{2011}.

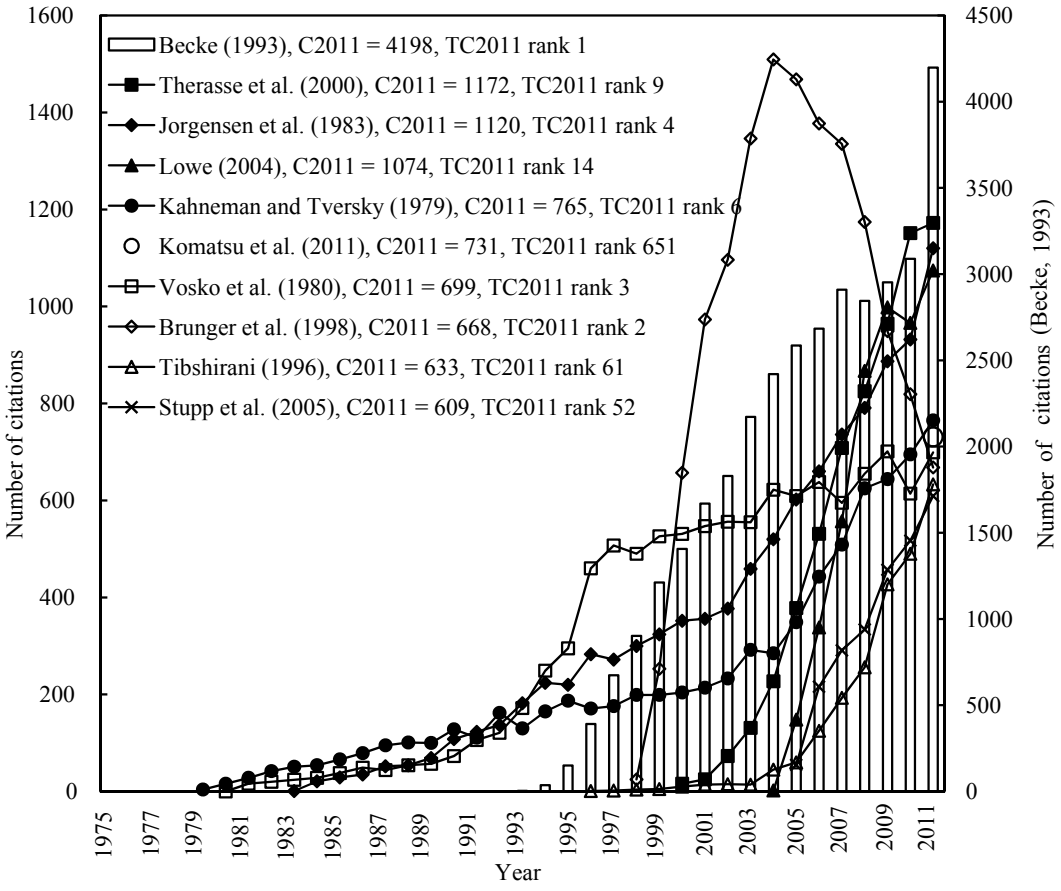

Figure 3
The Life of the Top Ten Most Cited Classic Articles in 2011 (C_{2011} > 600)

Information of total citations from Web of Science was applied in most studies. In this study, the total number of times in article cited from its publication to the end of 2011 (TC_{2011}) was used. It was noticed that the advantage of this indicator was its invariance, not updating as time goes on (Fu et al., 2012). Impact of top cited articles in total citation after publication with citation lives was recently presented (Fu et al., 2012; Khan & Ho, 2012). The

citation lives of the top nine articles (TC_{2011} > 6,000) are shown in Figure 4. Two articles were published in 1970s, three in 1980s, three in 1990s, and one in 2000s. Two articles by Becke (1993) and Jorgensen et al. (1983) were published in *Journal of Chemical Physics* with IF_{2011} = 3.333. Articles by Becke (1993) and Cockcroft and Gault (1976) were Canadan independent publications. Articles by Becke (1993) were the only one single author and institution publication. The Canadan independent article published by Becke in 1993 was the super cited article ranked 1st in TC_{2011}. The article was also the leader in terms of annual citations in 2011 Canada. Articles by Becke (1993), Brünger et al. (1998), Vosko et al. (1980), Jorgensen et al. (1983), Kahneman and Tversky (1979), and Therasse et al. (2000) all ranked top ten in both C_{2011} and TC_{2011}. The article with the highest TC_{2011} can be considered the most popular article in Canada's research.

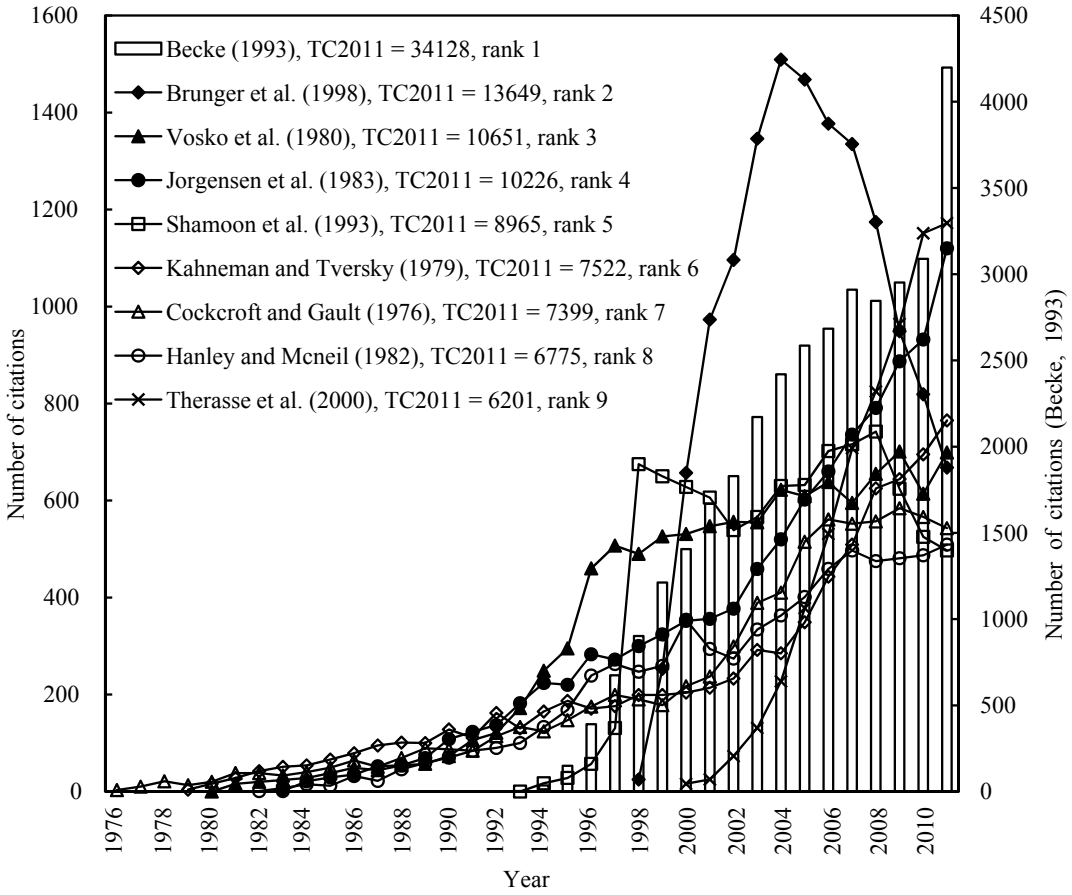

Figure 4
The Life of the Top Nine Most Cited Classic Articles (TC_{2011} > 6,000)

2.4 Institutional and Individual Contributors

Bibliometric indicators including total number of articles, independent articles, collaborative articles, first author articles, corresponding author articles, and single author articles (Chiu & Ho, 2005; Li & Ho, 2008; Ho, 2012) were applied to evaluated publication performance of the countries, institutions, and authors. A total of 31,351 classic articles by 113,801 authors from Canada and other 126 countries were evaluated. Only 17,522 authors, 15% of 113,801 authors, had both first and corresponding author Canada highly cited articles, while 92,857(82%) authors had no first author article and 94,595(83%) authors had no corresponding author article. Table 1 shows the top 30 Canadan institutions, ranked according to the total number of highly cited Canada articles. This includes the constants of the *Y*-index (*j*, *h*), the number and percentage of single Canada institution highly cited articles and inter-institutionally collaborative articles as well as the first author, corresponding author, and single author articles. University of Toronto ranked first with 5,939(20%) highly cited Canadan articles, followed by McGill University (3,594 articles, 12%) and University of British Columbia (3,013 articles, 10%). These universities were also rank top three in institutional independent articles, inter-institutionally collaborative articles, first author articles, corresponding author articles, and single author articles. Among the top 30 institutes, eight (27%) which were non-university institutions, were five hospitals and three research institutions including National Research Council

Canada, Fisheries & Oceans Canada, and Ontario Cancer Institute. Five hospitals had less independent articles. Low independent articles for hospitals were also reported in the top-cited research articles in the SCI-Expanded (Ho, 2012). *Y*-index parameters *j*, publication intensity constant and *h*, publication character constant were calculated. The rank of total highly cited Canada article (*TP*) and the rank of *j* for institutions were not the same. Only 10 institutions, including the top five, had the same rank of *TP* and *j*. Twenty institutions in Table 1 were changed, while seven were decreased and 13 were increased when compare rank of *TP* and *j*. Institutions with higher *j* for example University of Toronto, McGill University, University of British Columbia, Mcmaster University, and University of Alberta as well as National Research Council Canada and Hospital Sick Children had higher importance in highly cited Canadan articles. Furthermore, 11 institutions in Table 1 with $h > 0.7854$ had more corresponding author articles for example Toronto General Hospital, Montreal General Hospital, and Princess Margaret Hospital. Fifteen institutions with $h < 0.7854$ had more first author articles, such as University of Calgary and University of Laval. The performance that hospitals had more corresponding articles than first author articles was also reported in the top-cited articles in the SCI-EXPANDED (Ho, 2012b). On average, the research quality of a university improves some years after it appoints a president (vice chancellor; rector) who is an accomplished scholar (Goodall, 2009). However, it was pointed that the participation of highly cited scientists in the top leadership of universities is limited (Ioannidis, 2010). *Y*-index might be a useful indicator for the evaluation of applications by such senior figures. Figure 5 displays the distribution of the top 50 authors with $j \geq 25$ ($j\ Cos\ h$ and $j\ Sin\ h$ are chosen as the x and y coordinate axes). Publication character *h* could help obtain the different proportion of corresponding author articles to first author articles. Each dot represents one value that could be one author or many authors. The authors who contributed the most classic article were S. Yusuf ($j = 60$), followed by M. Steriade ($j = 57$) and G. H. Guyatt ($j = 50$).

Table 1
Characteristics of the Top 30 Institutions

Institution	TP	*TP R* (%)	*IP R* (%)	*CP R* (%)	*FP R* (%)	*RP R* (%)	*SP R* (%)	*S*%	Rank (*j*)	*h*
University of Toronto	6,126	1 (20)	1 (14)	1 (22)	1 (9.2)	1 (9.1)	1 (12)	26	1 (5761)	0.7793
McGill University	3,702	2 (12)	2 (10)	2 (13)	2 (6.1)	2 (6.0)	3 (7.7)	30	2 (3804)	0.7786
University of British Columbia	3,100	3 (10)	3 (8.8)	3 (10)	3 (5.3)	3 (5.3)	2 (8.8)	32	3 (3328)	0.7830
Mcmaster University	2,084	4 (6.6)	5 (5.9)	4 (7.1)	4 (3.7)	4 (3.6)	4 (4.5)	32	4 (2298)	0.7810
University of Alberta	1,801	5 (5.7)	4 (6.0)	6 (5.6)	5 (3.4)	5 (3.4)	6 (4.3)	37	5 (2134)	0.7873
University of Montreal	1,428	6 (4.6)	10 (2.7)	5 (5.6)	7 (2.0)	7 (2.0)	11 (2.3)	29	7 (1236)	0.7822
University of Western Ontario	1,207	7 (3.8)	6 (3.7)	8 (3.9)	8 (2.0)	8 (2.0)	5 (4.3)	32	8 (1234)	0.7822
University of Calgary	1,142	8 (3.6)	8 (3.2)	9 (3.9)	6 (2.0)	6 (2.0)	14 (1.8)	32	6 (1255)	0.7766
Hospital Sick Children	1,020	9 (3.3)	18 (1.3)	7 (4.4)	10 (1.8)	10 (1.8)	27 (0.60)	33	10 (1133)	0.7880
National Research Council Canada	949	10 (3.0)	7 (3.4)	12 (2.8)	9 (2.0)	9 (2.0)	8 (3.3)	32	9 (1229)	0.7846
University of Ottawa	879	11 (2.8)	15 (2.1)	10 (3.2)	16 (1.3)	16 (1.3)	13 (2.1)	31	16 (829)	0.7770
University of Laval	834	12 (2.7)	13 (2.4)	12 (2.8)	13 (1.4)	13 (1.4)	24 (0.83)	33	13 (880)	0.7718
University of Manitoba	809	13 (2.6)	12 (2.4)	15 (2.7)	14 (1.4)	14 (1.4)	15 (1.7)	33	14 (871)	0.7774
Queens University	805	14 (2.6)	14 (2.3)	14 (2.7)	12 (1.5)	12 (1.5)	10 (2.9)	32	12 (939)	0.7865
Dalhousie University	761	15 (2.4)	11 (2.4)	16 (2.4)	15 (1.4)	15 (1.3)	7 (3.5)	30	15 (846)	0.7830
University of Waterloo	730	16 (2.3)	9 (3.0)	17 (2.0)	11 (1.6)	11 (1.6)	8 (3.3)	30	11 (1012)	0.7874
Mount Sinai Hospital	615	17 (2.0)	57 (0.12)	11 (3.0)	18 (0.89)	18 (0.89)	62 (0.14)	26	18 (557)	0.7836
University of Guelph	547	18 (1.7)	16 (1.9)	18 (1.6)	17 (1.0)	17 (1.0)	12 (2.2)	26	17 (655)	0.7869
University of Saskatchewan	430	19 (1.4)	17 (1.4)	20 (1.4)	19 (0.79)	19 (0.8)	18 (1.2)	30	19 (500)	0.7894
Simon Fraser University	353	20 (1.1)	19 (1.1)	24 (1.1)	21 (0.63)	20 (0.63)	17 (1.3)	27	20 (394)	0.7854
University of Victoria	350	21 (1.1)	25 (0.65)	19 (1.4)	27 (0.44)	24 (0.45)	25 (0.73)	27	24 (279)	0.7890

To be continued

Continued

Institution	TP	*TP R* (%)	*IP R* (%)	*CP R* (%)	*FP R* (%)	*RP R* (%)	*SP R* (%)	*S*%	Rank (*j*)	*h*
Memorial University of Newfoundland	307	22 (1.0)	20 (0.86)	28 (1.0)	23 (0.50)	22 (0.50)	22 (1.0)	30	22 (312)	0.7854
York University	304	23 (1.0)	21 (0.82)	27 (1.1)	22 (0.51)	21 (0.51)	20 (1.1)	30	21 (320)	0.7854
Toronto General Hospital	280	24 (0.89)	36 (0.25)	22 (1.3)	31 (0.40)	26 (0.43)	37 (0.37)	30	27 (261)	0.8199
Montreal General Hospital	276	25 (0.88)	45 (0.16)	21 (1.3)	32 (0.39)	28 (0.41)	38 (0.32)	26	29 (253)	0.8131
Princess Margaret Hospital	267	26 (0.85)	37 (0.23)	23 (1.2)	35 (0.34)	32 (0.35)	46 (0.23)	27	32 (219)	0.7991
Fisheries & Oceans Canada	254	27 (0.81)	23 (0.80)	34 (0.82)	24 (0.47)	23 (0.47)	16 (1.6)	27	23 (296)	0.7854
University of Sherbrooke	245	28 (0.78)	24 (0.75)	35 (0.80)	30 (0.41)	29 (0.41)	29 (0.50)	27	28 (255)	0.7815
University of Quebec	243	29 (0.78)	29 (0.47)	31 (0.95)	34 (0.36)	31 (0.36)	32 (0.46)	22	31 (225)	0.7898
Ontario Cancer Institute	240	30 (0.77)	45 (0.16)	25 (1.1)	35 (0.34)	33 (0.34)	78 (0.092)	20	33 (215)	0.7807

Note. *TP*: Total number of highly cited Canada articles; *IP*: number of institutional independent articles; *CP*: number of inter-institutionally collaborative articles; *FP*: number of first author articles; *RP*: number of corresponding author articles; *SP*: number of single author articles; *R*: rank; *S*%: percentage of institutional independent articles in an institution; *j*: *Y*-index parameter, publication intensity constant; *h*: *Y*-index parameter, publication character constant.

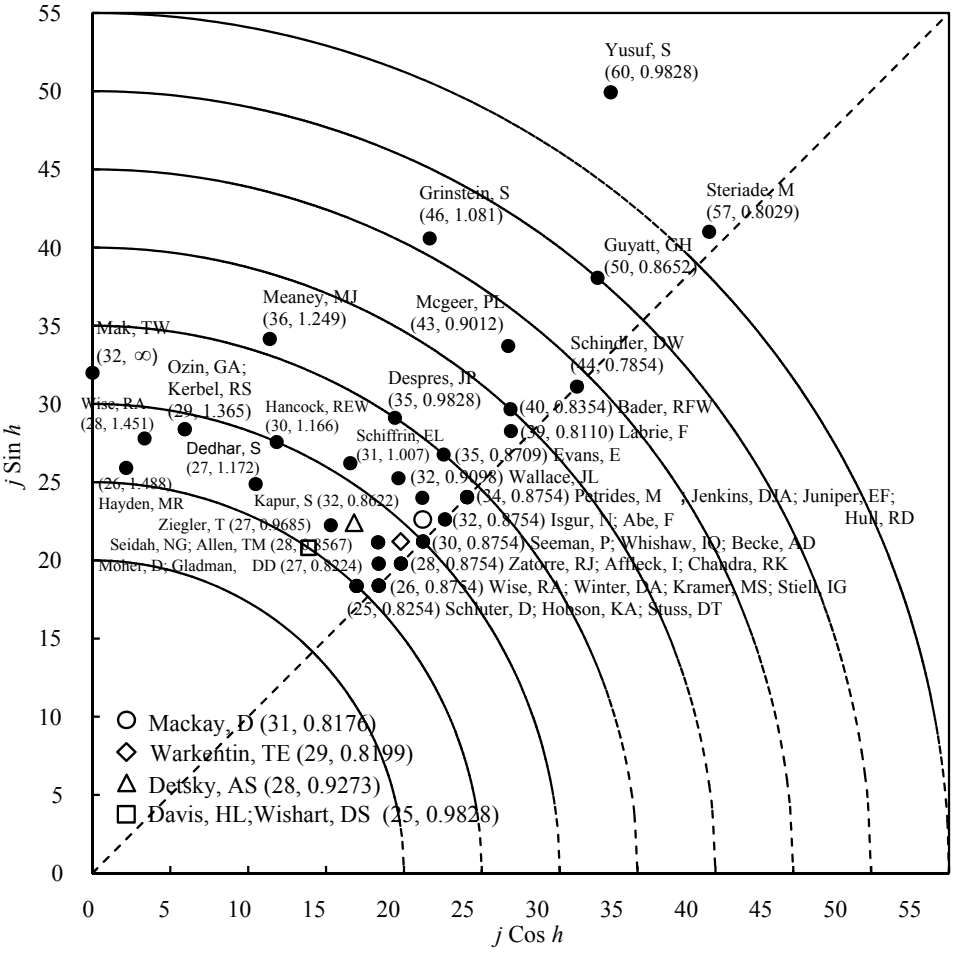

Figure 5
***Y*-Index of the Top 50 Authors With the Greatest *j* ($j \geq 25$)**

The 1st position S. Yusuf from Hamilton Health Sciences and McMaster University, published the most corresponding author highly cited Canada articles (36 articles) and 24 first author articles. That means the

author had not only high research but also supervises performance. Yusuf's most popular article was concerned about "Effects of an angiotensin-converting-enzyme inhibitor, ramipril, on cardiovascular events in high-risk patients" (Yusuf et al., 2000) (TC_{2011} = 4,355) in *New England Journal of Medicine*. The 2nd place M. Steriade from the University of Laval, published the most first author articles (29 articles) and 28 corresponding author articles. The most cited article of Steriade with TC_{2011} = 1,552 was entitled "Thalamocortical oscillations in the sleeping and aroused brain" (Steriade et al., 1993) in 1993. Seventeen of 50 authors in Figure 5 had $h = 0.7854$, just on the boundary of 0.7854 line owning the same quantity first authors articles and corresponding author articles. The other 33 authors had more corresponding author articles than first author articles ($h > 0.7854$). T.W. Mak had only 32 corresponding authors with $h = \pi/2$. Most top authors had more corresponding author articles than first author articles, an indication that the leading authors were more likely to be the corresponding authors than the first author. These authors might be senior researchers who supervise research students more. In addition, publication character h is very helpful especially when j of authors is the same. For example, the j of J.P. Despres and E. Evans were 35 for all but their h were 0.9828 and 0.8709, respectively, which meant that Despres had greater proportion of corresponding author articles for first author articles than that of Evans. A potential bias would appear in the analysis of authorship of authors who use the same name and those who use different names in their publications. Another potential confounding arises when an author moves from one affiliation to another. It is strongly recommended that an "International identity number" for all authors when they published their first paper in a Web of Science-listed journal (Chiu & Ho, 2007).

CONCLUSION

In total, 31,351 highly cited Canada articles with at least 100 citations since publication to 2011 were found in Science Citation Index Expanded from 1920 to 2012. The most highly cited Canada articles by decades were published in 1990s and the highest citations per publication were found in 1920s. These highly cited Canada articles were published in 2,452 journals in 174 Web of Science categories. *Journal of Biological Chemistry* was the most productive journal, and then *Nature*, *Proceedings of the National Academy of Sciences of the United States of America*, and *Science*. The most common category was observed to be biochemistry and molecular biology. The highly cited Canada articles would not be always in high impact after their publications. Most highly cited Canada articles had low citations in their publication year. In addition, the Y-index was successfully used to evaluate and characterize publications of authors, institutions, and countries. It is easy to find authors' publication characteristics from the figure of *Y*-index distribution. University of Toronto was the most productive institution in the highly cited Canadan articles. S. Yusuf in Hamilton Health Sciences and McMaster University published the most highly cited Canadan articles.

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