

CITATION CLASSICS IN APPLIED BIOMECHANICS OF SPORTS

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This study documented the top cited research articles, reviews, and books in the biomechanics of sports performance. A systematic search of Scholar Google records for “biomechanics” and at least one of the terms “sport” and “sports” was conducted. Publications focusing on exercise, injury, or basic science were excluded. Over 118,000 records were indexed and the top twenty were ranked by citations. Highly-cited papers were focused on running, throwing, and jumping. There was limited agreement between articles highly cited and those nominated as influential in a previous survey of sports biomechanics scholars, supporting previous concerns about citation counts as a surrogate measure of the importance of scientific publications in applied sports biomechanics.

KEY WORDS: bibliometrics, book, reference, research, review.

INTRODUCTION: Science builds knowledge on the consensus of research and theory published in the peer reviewed literature. The advancement of a scientific field, like sports biomechanics, depends on the acceptance of a structured, coherent body of knowledge. Attempts to quantify the impact of a publication on a field have focused on the number times it is cited in subsequent research (Smith & Rivett, 2009). Garfield (1987) reported the top cited papers in medicine and called them “citation classics.” Since then numerous studies have reported citation classics in a variety of disciplines and journals from biology (Picknett & Davis, 1999), cardiovascular medicine (McAlister et al., 2011) occupational medicine (Gehanno et al., 2007), to physical medicine and rehabilitation (Key, 1988; Shadgan et al., 2010).

Biomechanics is a relatively new scientific discipline and bibliometric research on this field has focused on the establishment of peer ratings of influential journals (Knudson, 2007; Knudson & Chow, 2008; Knudson & Ostarello, 2008). Knudson and Ostarello (2010) were the first to report peer nominations of influential books and research papers in sports biomechanics. They reported that in a survey of international scholars there was little agreement on influential books and original research in sports biomechanics, with 47 different books and 92 different articles being nominated as “most influential in applied sports biomechanics.” Zernicke et al. (2012) reported areas where biomechanics research has made major contributions to human health.

This study extended the identification of influential publications in the biomechanics of sports performance by documenting citation classics of original research, research reviews, and books based on citations indexed in Scholar Google (SG). New disciplines like sports biomechanics might tend to rely on scholarly books rather than research articles to provide initial direction to research. For example, a SG search for the term “biomechanics” returns over 404,000 records, with two books with over 5300 citations (Fung, 1993; Winter, 2009). SG was selected for searching the literature because it provides the most comprehensive coverage of a variety of journals and books in numerous languages over a longer time period with citation counts. SG has limitations compared to other commercial databases (Falagas et al., 2008; Schultz, 2007), however these other databases provide limited coverage of all literature and recent comparison indicates that SG outperforms most databases on locating relevant sources and excluding irrelevant sources (Walters, 2009)

METHOD: The author used the advanced SG search (<http://scholar.google.com>) for the term “biomechanics” with at least one of the terms “sport” or “sports.” The database was searched and reviewed numerous times from April 2, 2012 until December 14, 2012. Since SG limits the review of searches to the top 1000 records, multiple time ranges (down to single years)

were searched with these same terms to ensure that all relevant publications were examined. Further review of the records returned was conducted to ensure that citations actually referred to publications on the biomechanics of sports performance. Publications were included if the primary topic focused on a sport, a fundamental movement common in sports and athletics, or equipment specific to sports. In several cases the source needed to be accessed and reviewed to classify the publication as focused on applied sports biomechanics. Publications on general sports science, basic science, or injury mechanisms and prevention were excluded. For example studies of the biomechanics of concussions, walking, landing, cutting, knee or ankle injuries were excluded as these topics have recently been heavily researched and cited. Likewise, studies on training or neuromuscular factors using biomechanical methods were not considered applied sports biomechanics research.

Sports biomechanics publications indexed in SG and meeting the inclusion criteria were recorded and their number of citations in the database entered into an Excel spreadsheet. Articles, reviews, and books were ranked by the number of citations in GS. Citation rates were calculated relative to the original date of publication. The top twenty of each publication type sorted by citations are reported here due of proceedings page limitations.

RESULTS: Over 118,000 records were returned for the search. The top twenty cited articles and review articles in sports biomechanics are listed in Table 1. The top books in sports biomechanics are listed in Table 2. The citation rate of top publications varied widely (1 to 30 citations per year).

Table 1
Top Twenty Cited Original Research and Review Articles on Sports Biomechanics in Scholar Google

Original Research	Cites	CR	Reviews	Cites	CR
Cavanagh et al. 1980 <i>J Biomech</i>	524	16.4	Pappas et al. 1985 <i>AJSM</i>	289	10.7
Fleisig et al. 1995 <i>Am J Sports Med</i>	515	30.3	Mero et al. 1992 <i>Sports Med</i>	270	13.5
van ingen Schenau 1988 <i>J Biomech</i>	280	11.7	Dillman 1993 <i>JOSPT</i>	246	13.0
Jobe et al. 1984 <i>Am J Sports Med</i>	271	9.7	Putnam 1993 <i>J Biomech</i>	231	12.2
Gowan et al. <i>Am J Sports Med</i>	240	9.6	Lees 1998 <i>J Sports Sci</i>	214	15.3
Fleisig et al. 1999 <i>J Biomech</i>	236	18.2	Mann 1980 <i>Am J Sports Med</i>	201	6.3
Munrow et al. 1987 <i>J Biomech</i>	229	9.2	Fleisig et al. 1996 <i>Sports Med</i>	185	11.6
Mann et al. 1980 <i>Am J Sports Med</i>	202	6.3	Atwater 1979 <i>ESSR</i>	176	5.3
Werner et al. 1993 <i>JOSPT</i>	173	9.1	Toussaint 1992 <i>Sports Med</i>	155	7.8
Bobbert et al 1994 <i>MSSE</i>	165	9.2	Gregor et al. 1991 <i>ESSR</i>	149	7.1
Joris et al. 1985 <i>J Biomech</i>	149	5.5	Perry 1983 <i>Clin Sports Med</i>	143	4.9
Feltner 1989 <i>Int J Sport Biomech</i>	127	5.5	Anderson 1996 <i>Sports Med</i>	133	8.3
Mero et al. 1986 <i>Eur J Appl Physiol</i>	127	4.9	Clarys 1993 <i>J Sports Sci</i>	111	5.8
Hatze 1981 <i>J Biomech</i>	120	3.9	Williams 1985 <i>Ex Spot Sci Rev</i>	111	4.1
Dorge et al. 2002 <i>J Sports Sci</i>	103	10.3	Hume et al. 2005 <i>Sports Med</i>	96	13.7
Elliott et al. 1995 <i>J Appl Biomech</i>	102	6.0	Gainor et a. 1980 <i>AJSM</i>	85	2.7
van ingen Schenau 1982 <i>J Biomech</i>	102	3.4	van Ingen Schenau 1994 <i>SM</i>	86	4.8
Mann 1981 <i>MSSE</i>	101	3.3	Bartlett et al. 2007 <i>Sports Med</i>	72	14.4
Toussaint et al. 1988 <i>J Biomech</i>	97	4.0	Bartlett et al. 1996 <i>J Sports Sci</i>	72	4.5
Elliott et al. 1994 <i>J Biomech</i>	77	4.9	Lees 2002 <i>J Sports Sci</i>	71	7.1

Note: Citations indexed in Scholar Google as of December 14, 2012. CR is the citation rate or cites divided by years since publication. Articles that were also nominated as influential by respondents in the Knudson and Ostarello (2010) study are in **bold**. Respondents in that study were asked to nominate original research, but several spontaneously reported review papers.

DISCUSSION: This study showed limited agreement (25%) between highly cited original research in sports biomechanics with those previously nominated by content experts in the study by Knudson and Ostarello (2010). This supports similar differences between citation

counts and scholar ratings (McAlister et al., 2011), especially for single papers and small disciplines (Allen et al., 2009). There was qualitatively greater, but still not strong agreement (50%) between highly cited and previously nominated as influential books on sports biomechanics. This could be an artifact of substantially fewer books specifically focused on sports biomechanics.

Previous studies of expert ratings of journals (Knudson and Chow, 2008) and influential articles (Knudson and Ostarello, 2010) have noted trends of respondents to rate subject/sport area as highly as other factors in evaluating scientific value. The citation behavior documented in SG in this study also showed the influence of particular sporting movements. The most heavily cited papers were on overarm throwing/pitching (20-35%), running (20-25%), jumping (15%), and kicking (5-10%).

Table 2
Top Twenty Books on Sports Biomechanics Indexed in Scholar Google

Book	Cites	CR
Hay 1993 <i>Biomechanics of sports techniques</i> . 4 th ed. Prentice Hall.	670	17.2
Kreigbaum & Bartels 1996 <i>Biomechanics: a qualitative approach</i> . . . Allyn-Bacon.	409	13.2
Hamill & Knutzen 2006 <i>Biomechanical basis of human movement</i> . 3 rd ed. LWW.	329	19.4
Hamilton et al 2011 <i>Kinesiology: the scientific basis</i> . . . 12 th ed. McGraw Hill.	295	4.8
Hall 2011 <i>Basic Biomechanics</i> . 6 th ed. McGraw Hill.	283	13.5
Adrian & Cooper 1994 <i>Biomechanics of human movement</i>. WC Brown.	199	4.5
Miller & Nelson 1975 <i>Biomechanics of sport</i> . Lea & Febiger.	185	5.0
Knudson 2013 <i>Qualitative diagnosis of human movement</i>. 3rd ed. Human Kinetics.	180	12.0
Ackland & Elliott 2009 <i>Applied anatomy and biomechanics in sport</i>. 2nd ed. Blackwell.	162	9.0
McGinnis 2005 <i>Biomechanics of sport and exercise</i>. 2nd ed. Human Kinetics.	138	10.6
Bartlett 2007 <i>Introduction to sports biomechanics</i> . . . 2nd ed. Routledge.	123	8.2
Serig & Avvikar 1989 <i>Biomechanical analysis of the musculoskeletal</i> . . . Taylor & Francis.	103	4.5
Bartlett & Bussey 2011 <i>Sports biomechanics</i> . . . 2nd ed. Routledge.	73	5.6
Knudson 2007 <i>Fundamentals of biomechanics</i>. 2nd Springer.	62	6.7
Dainty & Norman 1987 <i>Standardizing Biomechanical Testing in Sport</i> Human Kinetics.	49	2.0
Zatsiorsky 2000 <i>Biomechanics in sports</i> . . . Blackwell.	26	2.2
Hochmuth 1984 <i>Biomechanics of athletic movement</i> . Sportverlag.	25	0.9
Vaughan (Ed) 1989 <i>Biomechanics of sport</i> . CRC Press.	20	0.9
Grimshaw et al. 2006 <i>Instant notes in sport and exercise biomechanics</i> . Taylor & Francis.	19	3.2
Watkins 2007 <i>An introduction to biomechanics of sport</i> . . . Elsevier.	9	1.8

Note: Citations and citation rate (from first edition) for books indexed in Scholar Google as of December 14, 2012. The most recent edition of books is reported, and books also nominated as influential by respondents in the Knudson and Ostarello (2010) study are in **bold**.

While SG may be the most complete database, it is limited in the dates of literature covered, biased toward English-language sources, and does not have some search features like other indexes (medical subheadings). Like all electronic databases there are errors in data input, inconsistency in wording used in titles, key words, and abstracts that hamper searching and retrieval of sources. There was also risk of bias and subjectivity in the author's classification of references as being primarily sports biomechanics. The study excluded highly cited biomechanics research related to injury, basic science, or training that could have relevance to sports. The results represent the citations in SG as of the reported date and given the rapid updating of the database, other scholars cannot easily replicate the study to confirm these time-limited results.

CONCLUSION: The use of SG was effective in identifying highly cited articles and books in applied sports biomechanics. It appears that much of the citation behavior in sports biomechanics may be related to the actual movements being analyzed and the rankings do not agree well with a previous study of scholar nominations of important sources (Knudson and Ostarello, 2010). These results when compared to this previous study also calls into question

the assumption that citations alone are a good indicator for scholarly contribution in the area of biomechanics of sports performance.

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