RECENT COLLABORATION TRENDS IN APPLIED BIOMECHANICS

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This study documented the recent changes in collaboration in original research in applied biomechanics. Original research articles (N = 132) published in 2005 and 2014 volumes of the *Journal of Applied Biomechanics* and *Sports Biomechanics* were reviewed to document several collaboration variables. There were no significant interactions with journal, so journal data were collapsed for comparison across years. There were significant increases in mean number of authors and in the complexity of design/statistics of 2014 research reports. Other collaboration variables were not different across this 10-year period. Overall the trend toward increased collaboration in applied biomechanics research reports may have only had a minor influence on increasing research quality.

KEY WORDS: authorship, design, sampling, statistics.

INTRODUCTION: Collaboration in medical and biological sciences research is common (Wuchty et al., 2007) with increasing rates of reports with numerous coauthors (Cronin, 2001; Weeks et al., 2004; Papatheodorou et al., 2008). Wang, Thijs, and Glanzel (2014) reported that there has also been a rapid increase in international research collaboration in the sport sciences from 2001 to 2011. In applied biomechanics, the rates of coauthorship tend to be similar to other sport/exercise sciences (Knudson, 2011), although there have been significant increases in coauthorship since 1984 (Knudson, 2012, 2016; Knudson & Bahamonde, 2012).

It is believed that greater collaboration will improve the quality and complexity of research. This ideal of synergy from collaboration, however, may not be achieved since the increasing rates of coauthorship in the biomedical sciences might also be consistent with no improvements in efficiency or quality of research (Papatheodorou et al. 2008). Excessive coauthorship or hyperauthorship (Flanagin et al., 1998) is often related to unethical authorship practices (Cronin, 2001; Al-Hertz et al. 2014; Rajaskaran et al. 2014) rather than meaningful collaboration. Unethical increases in coauthorship without meaningful collaboration also results from academic reward systems not prorating authorship credit (Franceschet & Costantini, 2010; Hagen, 2014; Liebowitz, 2014).

If sample size of applied biomechanics studies is used as a proxy for research quality, some studies (Knudson, 2012; Knudson & Bahamonde, 2012) support the hypothesis that there have not been significant improvements in research quality from the dramatic increases (71%) in coauthorship in biomechanics from 1984 to 2009. Given the lack of clarity of the potential effects of increasing collaboration in applied biomechanics, the present study sought to update the recent studies on this topic. The present study expanded the time frame and kinds of data on research quality in assessing potential changes in collaboration in applied biomechanics research.

METHOD: The author systematically reviewed the original research reports from the 2005 and 2014 volumes of *Journal of Applied Biomechanics (JAB)* and *Sports Biomechanics (SB).* Reviews, technical notes, and editorial correspondence were excluded from the study. These journals are key outlets for applied biomechanics research with continuous publication in the 10-year window needed to update the recent research (Knudson, 2012).

Five primary research collaboration dependent variables were retrieved from the text of each original research report by the author: the number of authors, sample size, number of data collection sites, number of independent variables, and complexity of design/statistics. Sample size was defined as the total number of subjects, animals, or material samples used in the experiment or series of experiments in the research report. New research quality variables examined were the number of independent variables used in the study, the number

of authors, and a 5-point design/statistics complexity score (DSC). DSC was a 4-point ordinal scale with one additional point for prospective/intervention designs over 4 weeks (Table 1). Two other variables were calculated to qualitatively compare with values reported by Knudson (2011, 2012): hyperauthorship rate was the percentage of papers with 6 or more authors (Flanagin et al., 1998) and the sample/author ratio.

Descriptive data ($m \pm sd$) were calculated and t-tests and Chi Squared were used to compare the four dependent variables across years for both journals since factorial (year by journal) ANOVAs of the continuous variables showed no interaction. Analyses of the sample size data were performed after removal of one substantial outlier (N = 644) from the 2014 volume of *JAB*. To control the experiment-wise error rate at $p < 0.05$, critical p values were corrected using a Holm's correction. The size of significant differences were reported using the effect size (d) using the sd from the baseline (2005) journal data.

Table 1
Design/Statistics Complexity (DSC) Score

Score	Characteristics	Examples
1	Descriptive study	Zero-order correlation or simple regression
2	Comparison study	t tests, ANOVA, Chi Squared
3	Factorial study	Factorial ANOVA or multiple regression
4	Multivariate study	MANOVA or structural equations modeling

Note: Score may be supplemented (+1) for a prospective/intervention study greater than four weeks.

RESULTS: Eighty-seven and 45 research reports from the *JAB* and *SB* met the inclusion criteria, respectively. The mean number of authors significantly ($p < 0.24$) increased from 2005 to 2014 (Table 2). Fisher's Exact test for Chi Square of the distribution of DSC scores were significantly ($p < 0.01$) different between 2005 and 2014 (Table 3). There were no significant differences in the number of independent variables and sample sizes between over this time period. The number of experimental sites were not compared because all studies were from one site, except for three studies (2.2%) from the whole sample. Qualitatively the rates of hyperauthorship in 2005 (13.2%) were similar to the 12.9% reported by Knudson (2011), which nominally increased to 16.7% in 2014. Mean sample/author ratios (5.9 and 6.3) were also qualitatively similar to those reported (5 to 9) by Knudson (2012) and Knudson and Bahamonde (2012) for 2009 volumes of biomechanics journals.

Table 2
Research Collaboration Indicators in Applied Biomechanics Journals

	2005	2014	*p*	*d*
Number of Authors	3.4 (1.6)	4.0 (1.4)*	0.024	0.41
Sample Size	17.3 (14.8)	22.8 (16.8)	0.078	
Independent Variables	1.6 (0.7)	1.8 (0.7)	0.145	

DISCUSSION: The moderate ($d = 0.41$) increase in coauthorship in applied biomechanics research reports over the last ten years agreed with increases previously reported up until 2009 (Knudson, 2012; Knudson & Bahamonde, 2012). The 2014 mean of 4 authors per paper was consistent with 2009 values (3.6 to 4.5), so perhaps the rate of increase in potentially promiscuous coauthorship in biomechanics is slowing. The rate of hyperauthorship in 2014 (16.7%) was nominally only slightly higher than the 13% in 2005 reported by Knudson (2012).

Table 3
Distribution of Design/Statistics Complexity Scores in Applied Biomechanics Journals (percent)

	2005	2014
1	29	13
2	24	32
3	42	44
4	5	10
5	0	1

Note: Distributions significantly ($p < 0.01$) different based on Fisher's Exact Chi Squared.

Increases in coauthorship could be expected to increase the quality and complexity of the research. This hypothesis was partially supported by the significantly different distributions of DSC from 2005 till 2014. Over ten years there were nominal reductions in the percentages of descriptive studies (Level 1) with increases in higher-level (Levels 2 to 5) designs and statistical analyses (Table 3). This increase (16%) in higher-level designs was nominally lower than the 19% increase in mean number of authors.

The other indicators of collaboration, however, did not show statistically significant improvements over the last ten years. Sample sizes (17 to 23) in the current study were qualitatively similar to 25 year sample sizes (15-42) previously reported (Knudson, 2012; Knudson & Bahamonde, 2012). Applied biomechanics, like other disciplines (Marszalek et al., 2011), has not improved samples sizes despite more coauthors, improvements in data collection, and recommendations to improve sample sizes. The mean number of independent variables (1.6 to 1.8) in applied biomechanics studies did not change over the last ten years. There was also clearly no increase in studies with multiple sites since both journals typically only had one study reporting two sites for data collection, with the vast majority of studies collecting data at one location. Intervention designs in applied biomechanics ware also quite rare with only 3 reports (4.5%) in 2014 volume of *JAB* testing prospective hypotheses.

The study was limited to the two years sampled and the two applied biomechanics journals studied. There could also be errors in the author's subjective classifications of DSC and there are other aspects of the complexity/quality of biomechanics research not correlated with the dependent variables in this study. The complexity of data collection, modeling, calculations, and novelty are all important research quality factors that were not directly measured in this study. The number of authors was a rather crude measure of research quality, so categories of coauthor collaboration could be explored in future studies.

CONCLUSION: Original applied biomechanics research reports published in *JAB* and *SB* from 2005 to 2014 show a continuation of recent collaboration trends of significant increases in numbers of coauthors. There were significant but smaller improvements in design/statistics complexity of the research resulting from this increased collaboration. Other hypothesized benefits of greater collaboration including sample size, independent variables, and multi-site data collection were not apparent. Overall the trend toward increased collaboration in applied biomechanics research reports may have only had a minor influence on improving research quality. The major increases in collaboration and team science in applied biomechanics research has not likely increased the quality of useful information for practitioners. Improvements in research quality and application recommendations from research (Knudson et al., 2014) are needed to fulfill the "bridge the gap" mission of the International Society of Biomechanics in Sports.

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