

BIOMECHANICS CONCEPT INVENTORY: VERSION TWO**Duane Knudson****California State University-Chico, Chico, CA, USA**

A new test of core biomechanics concepts (BCI2) was developed, administered to an introductory biomechanics class, and the results compared with a subsample of similar students tested with the original Biomechanics Concept Inventory (BCI). Following instruction mean student scores improved 33% that was equivalent to a normalized gain (g) of 24% of maximum possible improvement. Improvement scores were not significantly different from students at the same university who had taken the first version of the test. These results support the previous study and provide normative data for evaluating learning in introductory biomechanics. The new questions on the BCI2 may be substituted for similar items in the BCI to help instructors construct customized tests to evaluate new instructional strategies.

KEY WORDS: standardized test, learning, instruction, evaluation.

INTRODUCTION: A variety of standardized tests of mechanics concepts have been published in the physics literature (Halloun & Hestenes, 1985; Hestenes et al. 1992; Hestenes & Wells, 1992; Thornton & Sokoloff, 1998). Recently, a test of core biomechanics concepts for the undergraduate introductory biomechanics class has been published with national norms (Knudson et al. 2003). This test, the Biomechanics Concept Inventory (BCI) showed good reliability. BCI data from a study of a national sample of students were consistent with studies of physics classes, in that, typical students had difficulty mastering biomechanics. Improvement in BCI scores across a semester for most students was only about 30 percent. Learning data from tests like the BCI provide a standard on which instructional changes can be evaluated. The purpose of this study was to develop another version of the BCI and compare improvement to a subsample of the original BCI data from the same university.

METHOD: A 24-question test (BCI2) was written to be consistent in format with the original Biomechanics Concept Inventory (Knudson et al. 2003). The BCI2 also has two questions for eight biomechanical competencies and four prerequisite competencies. These core competencies come from the biomechanics course guidelines developed by the Biomechanics Academy of the National Association for Sport and Physical Education (NASPE, 2003). The BCI was shown to have content validity and to provide reliable scores to about 1 to 2 questions (Knudson et al. 2003). The test questions for the BCI2 may be obtained by contacting the author by email at: dknudson@csuchico.edu.

An introductory biomechanics class with 11 females and 19 males took the BCI2 at the beginning and at the end of a 15-week semester. This class was compared to a similar class what took the BCI ($n = 28$, 11 female and 17 male) from the original study (Knudson et al. 2003). Descriptive statistics were calculated for the pretest and posttests, and improvement was with percentages and Hake's (1998) normalized gain (g). Mean gain scores between the two classes were compared with a t test with statistical significance accepted at $p < 0.05$.

RESULTS: The descriptive data for the pretest, posttest, and gain scores are reported in Table 1. Mean (sd) pretest scores were higher (10.2 ± 2.0) compared to the students from the same university who took the BCI version one (8.6 ± 2.7). Improvement in posttests for both tests was similar for the BCI2 (33%) and (37%) for the BCI. The mean posttest scores for the BCI and BCI2 indicate that typical students at this university master 50 to 58 percent of the introductory biomechanics competencies. There was no significant ($t_{56} = -0.23$, $p < 0.82$) difference in mean gain scores between the BCI2 and BCI for students from the same university. Students tested with the BCI from this university had mean normalized gains of 24 ± 20 percent. Mean gain score for the national sample of the BCI was 13 ± 20 percent (Knudson et al. 2003).

Table 1 BCI2 Pretest, Posttest, and Gain Scores.

	Pretest	Posttest	Gain*
Mean	10.2	13.6	24
SD	1.9	2.7	18
Max	14	19	64
75%	11	15	32
50%	10	14	27
25%	9	12	13
Min	7	8	0

* Gain scores are percent of the maximum possible improvement for each subject (Hake, 1998).

DISCUSSION: The mean pretests and posttests of the BCI2 were one to two points higher than the BCI for students from the same university. It appears that the class that took the BCI2 may have been more prepared to take the introductory biomechanics class, although the reliability of the BCI and BCI2 are likely limited to differences of one to two points (Knudson et al. 2003). Both the BCI and BCI2 documented a modest mean increase in scores of about three points. The normalized improvement in scores between the two tests (24%) was not significantly different. This was expected as there was no change in textbook or instructional techniques, and it appears that the BCI and BCI2 have similar difficulty. It is clear from these data and the original BCI results (Knudson et al. 2003) that most introductory biomechanics students find it difficult to master core biomechanics concepts. This is consistent with the research on introductory mechanics in physics classes. Traditional instruction in mechanics only results in gain scores between 12 and 28 percent (Hake 1998; Redish, 1999; VanDomelen & VanHeuvelen, 2002), while new pedagogies can have mean improvements between 37 and 70 percent (Meltzer & Manivannan, 2002; Redish, 1999). Overcoming the difficulty of most students in learning biomechanical concepts with instructional innovations is an important area of future research.

Results of this study and Knudson et al. (2003) indicate the BCI and BCI2 may be used to evaluate the effect of instructional strategies on the learning of key biomechanical concepts. Normative data for these tests allow instructors to compare student performance to national norms, while repeated testing over several semesters will allow the evaluation of new instructional strategies on student learning. For example, recent research has shown organizing biomechanics instruction around real-world problem solving using mechanical principles improves student interaction and interest (Roselli & Brophy, 2003). The BCI or BCI2 could be used to see if similar instructional strategies using biomechanics principles (Knudson, 2003) also improve student learning. It is also possible that instructors could select questions from both the BCI and BCI2 that best fit their instructional objectives to create a customized tool for evaluating student learning in their biomechanics courses.

CONCLUSION: The new test of core biomechanics concepts (BCI2) showed modest amounts of improvement in mastery of these concepts following instruction. This modest improvement was similar to other mastery of mechanics concepts following physics instruction. The BCI 2 and BCI (Knudson et al. 2003) are tools that can be used to help biomechanics instructors evaluate new instructional strategies designed to alleviate the difficulty most students have in learning important biomechanical concepts.

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