Study of golf swings pinpoints biomechanical differences between pros and amateurs

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When it comes to hitting a golf ball hard, researchers at the Stanford University School of Medicine have identified several biomechanical factors that appear to separate the duffers from the pros.

For the first time, several key rotational-biomechanic elements of the golf stroke in its entirety, from backswing to follow-through, were analyzed, and then the data were used to generate benchmark curves, said Jessica Rose, PhD, associate professor of orthopaedic surgery and senior author of the study. She and her fellow researchers found that swing biomechanics were highly consistent among a group of professional players. At certain phases of their swings, their movements were almost indistinguishable from one another.

"The set of biomechanical factors we examined were selected to capture the essential elements of power generation," Rose said. The lead author of the study is former Stanford medical student David Meister, MD.

The findings, scheduled to be published online July 29 in the *Journal of Applied Biomechanics*, could be used to help improve golfers' ability to hit the ball farther and do so without increasing their risks of injury. The authors point to studies showing that improper swing biomechanics is the leading cause of golf-related injuries. They also cite studies showing that 26-52 percent of golf-related complaints involve lower-back injuries, 6-10 percent involve shoulder injuries and 13-36 percent involve wrist injuries.

"Over-rotation is one of the leading causes of back injury," Rose added.

Researchers collected data for the study using an array of eight special digital cameras in the Motion & Gait Analysis Laboratory at Lucile Packard Children's Hospital at Stanford. Using the same precise technology they typically use to analyze gait and upper limb movement disorders, they recorded three-dimensional motion images of the golf swings of 10 professional and five amateur male players. Among the five non-professional golfers, one was a college-level amateur with a handicap of 4; two were amateurs with handicaps of 15 and 30, respectively; and two were novices. Most of the professional players were alumni of the Stanford Men's Golf Team.

Although men were the exclusive subjects of this study, Rose said the findings likely extend to women, as well, but need to be examined.

Researchers analyzed several biomechanical elements of subjects' golf swings, including S-factor (tilt of the shoulders), O-factor (tilt of the hips) and X-factor — the relative rotation of the hips to the shoulders, measured in degrees — which is considered key to power generation. Previous research has shown that pro golfers who hit the ball far generally have a larger peak X-factor than their peers, but this study is more extensive in that it considers X-factor in relation to other rotational biomechanics of the golf swing over the full duration of the motion.

Among the 10 pros in this study, peak X-factor during a hard swing was highly consistent, varying just 7.4 percent from a mean of 56 degrees. Their club speeds at impact with the ball also were highly consistent, varying just 5.9 percent from a mean of 79 mph. In contrast, peak X-factor of the three least skilled amateurs — the handicap-30 golfer and two novices — fell below the professional range: 48, 46 and 46 degrees, respectively. These smaller X-factor angles correlated with slower club speeds at impact: 68, 66 and 56 mph, respectively.

In addition, the study describes S-factor, a term coined by the researchers, for the first time. S-factor is the angle or tilt of the leading shoulder relative to the level position. The researchers found that peak S-factor occurred right after impact and was highly consistent among the pros, varying just 8.4 percent from a mean of 48 degrees. The handicap-15 player and two novices had lower S-factors of 42, 42 and 33 degrees, respectively, while S-factors of the handicap-4 player and handicap-30 players both fell within the professional range.

The study also found that peak free moment — the golfers' turning force, or torque, measured using a special scale — was highly consistent among the pros, varying only 6.8 percent from a mean.

The authors conclude that peak free moment, X-factor and S-factor "are highly consistent, highly correlated to [club head speed at impact], and appear essential to golf swing power generation among professional golfers."

In addition, the researchers found overall biomechanical differences between the professionals and amateurs. "For example, the peak free moment of Novice #1 was reduced and delayed compared with the professionals," the authors note. "His X-factor was excessive in early backswing, but insufficient in downswing compared with professionals. Novice #2 had a reduced X-factor throughout backswing and downswing." Both of these players had lower club speeds at impact than the pros did.

"A precise understanding of optimal rotational biomechanics during the golf swing may guide swing modifications to help prevent or aid in the treatment of injury," they wrote.

Conrad Ray, the Knowles Family Director of Men's Golf at Stanford University and a co-author of the study, said the findings give scientific

backing to the elements of golf-swing form that professionals have long understood are vital for generating power. The study also helps to clarify some unresolved questions about golf-swing biomechanics, Ray said. "One question that always comes from students is, 'What starts the downswing?'" he said. "People have had different answers. Some would say the hands, or others would say the shoulders or the lower body. But the study confirms that rotation of the hips initiates the downswing. So that, to me, is an interesting finding."

Ray, who as the men's head golf coach led the Cardinal to five appearances in the NCAA championships and its eighth national title, in 2007, said the study validates the importance of X-factor in generating club speed. "All golfers want to know how to hit the ball longer, and this study support that speed is really a factor of relative body rotation," he said.

There were some limitations to the study. Although club speed at impact is a common measure for determining power generation, the authors note that they were unable to measure the outcome of the swings, such as distance and accuracy; measurements were made in a lab, with players hitting the ball into a net. "Down the road, it would be interesting to correlate ball data to the rotational biomechanics," Ray said.

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