BRIDGING THE GAP: KEY PRINCIPLES IN BIOMECHANICALLY GOOD GOLF SWINGS

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The purpose of this presentation was to provide an overview of key principles of biomechanically good golf swings and focus areas that have received substantial attention lately, such as the foot-ground interaction and the functional swing plane-based kinematic sequence analysis. More field-based research is required to develop a holistic understanding of the mechanics in good golf swings. Employment of realistic swing models and development of meaningful research questions and analysis methods in close consultation with golf practitioners is essential in the process.

KEYWORDS: evidence-based practice, functional swing plane, functional double pendulum, kinematic sequence.

INTRODUCTION: While numerous studies have been published on golf biomechanics over last 4-5 decades, a wide gap between science and practice still exists. Golf is a highly individualized sport and golf skill development is largely driven by instructors' experiences and preferences than scientifically validated facts and evidences. Thus, there is an ample room for improvement in terms of evidence-based practice.
A majority of biomechanical studies published previously, however, have based on simple planar double-pendulum model or its variations. While these studies allowed scientists to understand some key biomechanical/mechanical concepts such as "body-to-club energy transfer" and "effects of delayed release," the swing models employed were not complex enough to address the real issues practitioners are facing. Research findings are not well utilized in golf instruction due to weak instructor training infra structures.
To narrow the gap between science and practice, more realistic swing models should be employed and more field-oriented practical and meaningful research questions should be developed in consultation with golf practitioners. The main task for sport biomechanists is to develop a holistic big picture understanding of key principles of biomechanically good golf swings through field-based research working with golf practitioners. The purpose of this presentation is to provide an overview of key biomechanical principles and focus area that have received substantial attention lately.

FUNCTIONAL SWING PLANE: The functional swing plane (FSP) is the plane of motion of the club near the impact and is computed from the clubhead trajectory through a least-square fitting. Unlike other popular definitions of swing plane (mostly reference planes or body lines), FSP is a mechanically meaningful plane computed directly from the motion of the club in each swing. The FSP properties (slope, direction, and impact point on the plane) characterize golfer's swing (Figure 1). For example, slope of the FSP is closely related to the swing style of the golfer: arm-driven vs. body-driven. Projection to the FSP of the trajectories of the clubhead and key body points such as the lead hand and shoulder allows dissection of the motions into the on-plane motions on the FSP and the off-planes motions away from/toward the FSP (Figure 1). Based on the off-plane motion pattern, several distinct swing styles have been identified: such as planar swing, spiral swing, and reverse spiral swing (Figure 2).

FOOT-GROUND INTERACTION: One area that has received a substantial amount of attention recently is the effects of the foot-ground interaction on development of the angular motion of golfer's body. One main goal in a golf swing is to develop a large clubhead speed through angular motions of the body while maintaining control. The ground reaction force (GRF) and the ground reaction moment (GRM) acting on the body during the swing are the sole sources of angular momentum for the golfer-club system and the quality of the foot-ground interaction (i.e. magnitude, direction, and point of action of the GRF) thus is a key factor for a biomechanically good golf swing.

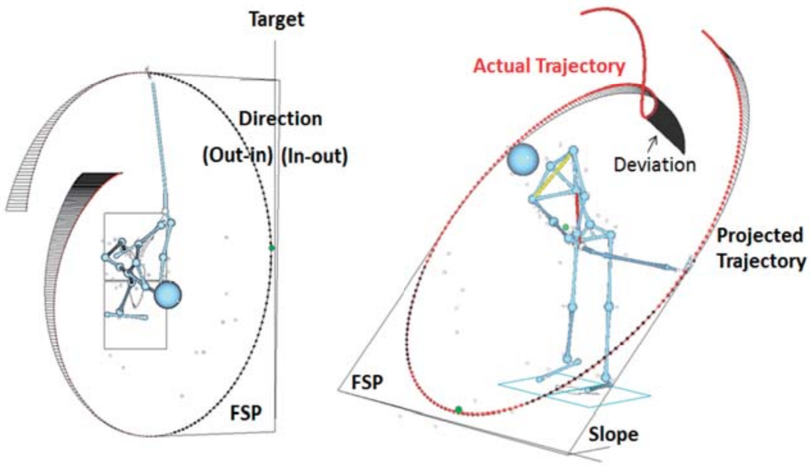

Figure 1. Properties (direction and slope) of a functional swing plane (FSP). The projected clubhead trajectory visualizes the on-plane and off-plane motion of the club.

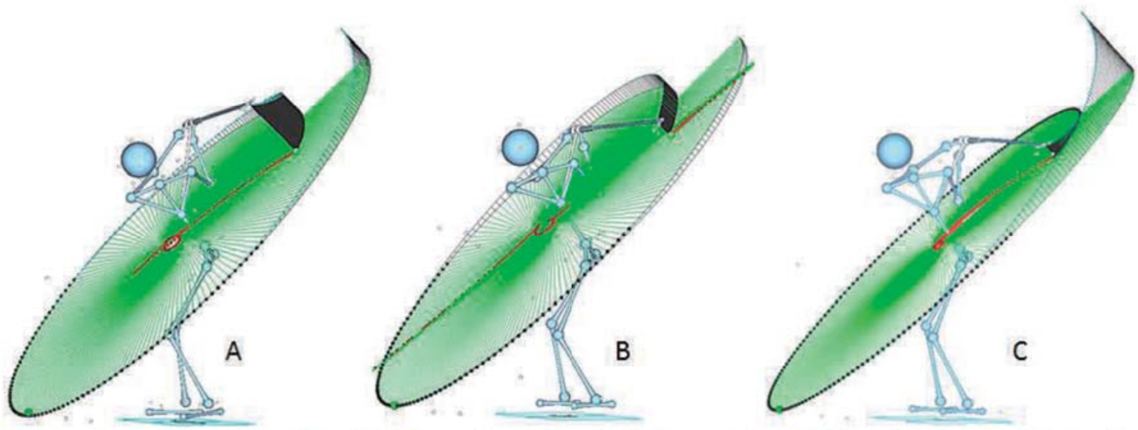

Figure 2. Swing styles classified based on the deviation of the clubhead trajectory from the functional swing plane (FSP): planar (A), spiral (B), and reverse spiral (C).

Moments are generated through three different mechanisms: GRF moment produced by the combined GRF about the center of mass (CM), pivoting moment produced by the individual GRFs about the combined center of pressure (COP), foot contact moments through the direct rotational foot-ground interaction. The main source of moment in the frontal plane of the body is the GRF moment while that in the transverse plane is the pivoting moment (Figures 3 & 4). It is ideal to use a movement pattern that allows early development of the frontal-plane GRF moment and pivoting moment during the backswing-downswing transition. While the pivoting moment pattern about the combined CP remains fairly similar across golfers, the frontal-plane GRF moment pattern varies significantly. Swing styles can also be classified based on the way the frontal-plane GRF moment is produced: moment arm-dominant, force-dominant, hybrid (moment arm and force), and double-peak patterns.
The quality of the foot-ground interaction is ultimately determined by the unbalanced actions of the leg muscles. As a result, pelvis motion, lateral tilt in particular, is a good indicator of the quality of the foot-ground interaction (Figure 5). A good foot-ground interaction is a key ingredient of the so-called ground-up swing.

FUNCTIONAL DOUBLE-PENDULUM AND KINEMATIC SEQUENCE: The functional double pendulum (FDP) model differs from the original model in several aspects. Firstly, the "moving" hub is located near the mid-trunk area where the FSP passes through and the upper lever consists of the thorax, shoulder girdles, and the arms. The length and position of the upper lever are determined by the motions of the thorax, shoulder girdles, and the arms.

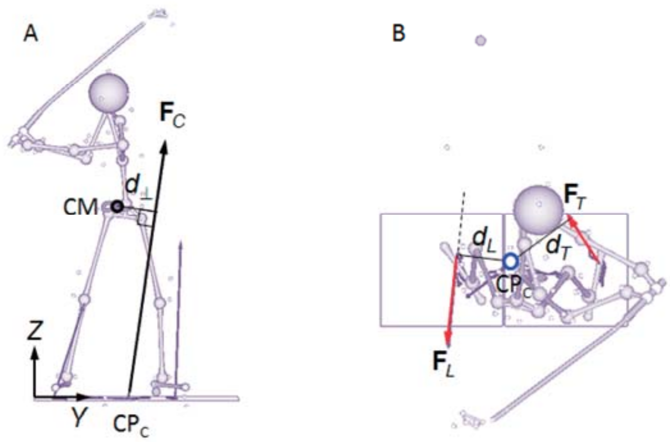

Figure 3. The main moments generated about the body CM through the foot-ground interaction: frontal-plane GRF moment (A) and transverse-plane pivoting moment (B). Symbols: F (force), d (moment arm), C (combined), L (lead side), and T (trail side).

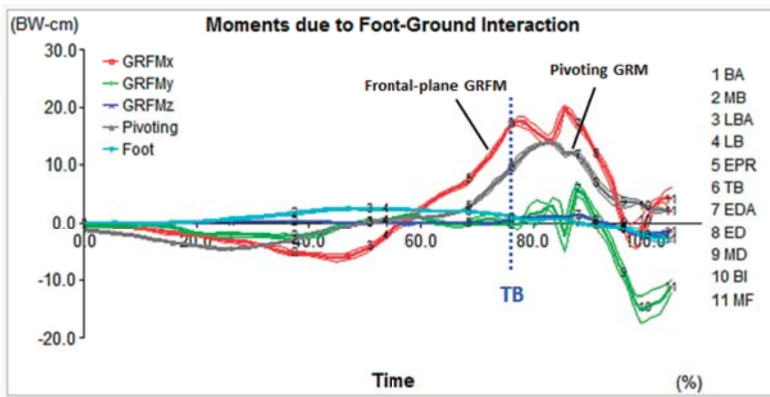

Figure 4. Ensemble average moment patterns of a male professional tour player (driver): frontal-plane GRF moment (red) and pivoting moment (gray). While the sagittal-plane GRF moment is reasonably large near the impact, its pattern is not consistent across golfers.

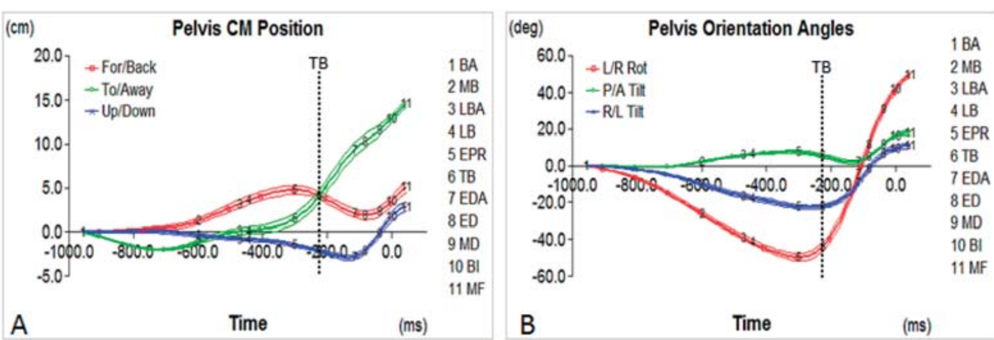

Figure 5. Ensemble average patterns of pelvis motion of a male professional tour player (driver): linear (A) and angular (B). The patterns were presented as the offset from the setup position.

The angular positions and velocities of the upper lever, lower lever, hip line, and shoulder line during the swing can be quantified on the FSP (Figure 6). The kinematic sequence can be examined in the perspective of proximal-to-distal transition sequence, the timing and magnitude of the peak angular velocities, changes in the peak angular velocities, and wrist lag angular velocity (i.e. delayed wrist release) (Figure 7). No x-factor or stretch measures are meaningfully associated with the clubhead speed in elite golfers.

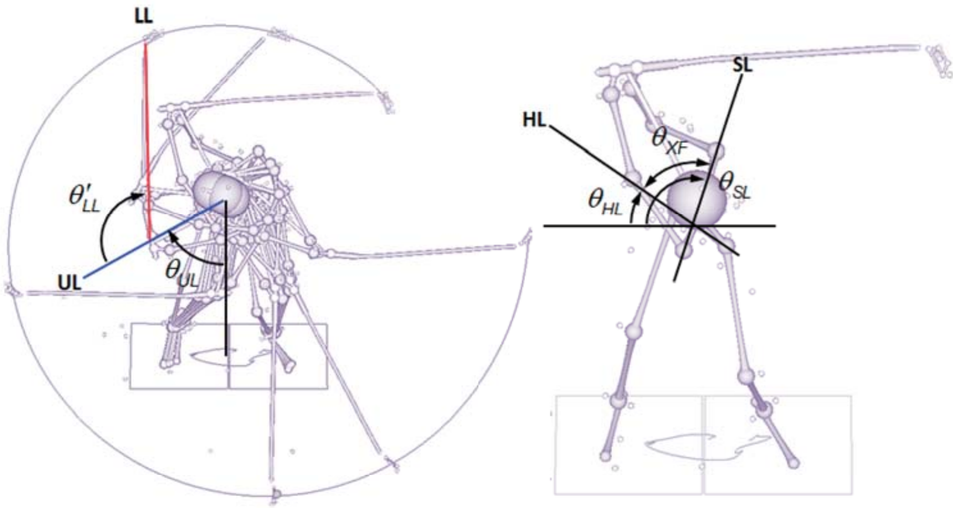

Figure 6. Angular positions of the levers and hip and shoulder lines in the FSP view. Abbreviations: UL (upper lever), LL (lower lever), HL (hip line), SL (shoulder line), and XF (x-factor).

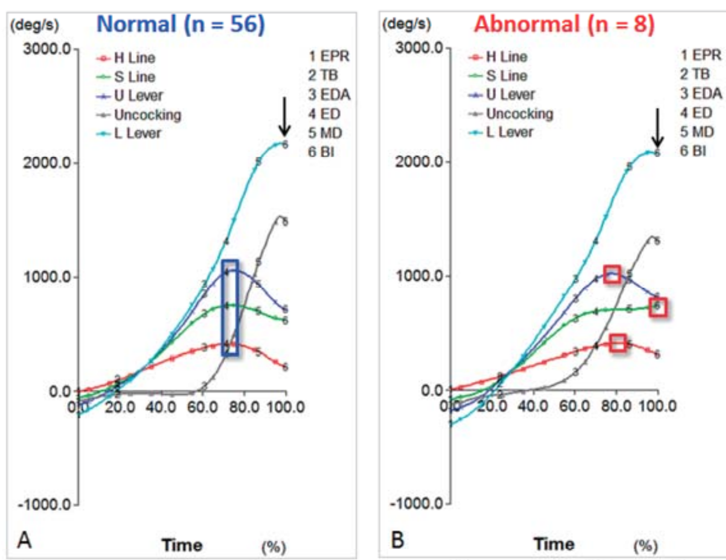

Figure 7. Ensemble average kinematic sequence patterns of elite golfers: normal (A) and abnormal (B). While proximal-to-distal transition sequences are observed in both groups, the abnormal group is characterized by delayed onsets of peak angular velocities.

SUMMARY: Two key biomechanical concepts in golf swing are (1) angular momentum generation by utilizing external forces and moments, and (2) angular momentum transfer within the body and from the body to the club. The foot-ground interaction is the key aspect in terms of angular momentum generation while the FSP-based angular motion measurement and the kinematic sequence are related to the aspect of angular momentum transfer. In addition to the foot-ground interaction and kinematic sequence mentioned here, new areas of interest are currently emerging, such as the hand-club kinetics, net joint moments generated at various body joints, and kinetic sequence.