The Effect of Club Length, Face Bulge Radius, and Center of Gravity Depth on Optimal Golf Drives – A Simulation Study

Spencer Ferguson[1], William McNally[1], and John McPhee[1]
[1] Systems Design Engineering, University of Waterloo, 200 University Ave W, Waterloo, ON, N2L 3G1, Canada

The driving distance of golfers at the elite level has been increasing since the 1990s, prompting golf's governing bodies to introduce a model local rule that decreases the maximum allowable club length from 48 to 46 in (1.22 to 1.17 m) [1]. In this study, we evaluate the potential efficacy of this rule change using a dynamic golfer-club model, and also investigate the optimal relationship between clubface bulge radius and clubhead center of gravity (CG) depth on mishit shots.

Both investigations employed the dynamic golfer and club model presented in [2]. The impulse-momentum impact model was augmented with the work presented in [3] to improve accuracy, while the ball flight model was updated to reflect contemporary golf ball aerodynamics [4]. The default club configuration used in these investigations was a 200 g, 9.5° lofted clubhead paired with a 65 g shaft with a generic stiffness profile. The optimal golf drives were generated using MATLAB 2021a's genetic algorithm (GA), where the biomechanical timings of the golfer were optimized to maximize the carry distance of the shot.

To determine the effect of club length on distance, the golfer model was given club lengths of 1.12, 1.17, and 1.22 m. The GA ran 25 optimizations for each club with a population size of 400 and 20 generations for each run. The best results for clubhead speed and carry distance of the optimal drives are shown in Table 1.

Table 1: Clubhead speed and carry distance for each club length's optimal drive

Club Length [m] (in)	Clubhead Speed [m/s] (mph)	Carry [m] (yds)
1.12 (44)	46.6 (104.2)	224.1 (245.1)
1.17 (46)	47.5 (106.2)	232.8 (254.6)
1.22 (48)	47.9 (107.2)	236.8 (259.0)

Increasing the length of the club had a positive correlation with both clubhead speed (r = 0.982) and carry (r = 0.978). A rule to limit club length to 1.17 m might help curb future distance gains at the elite level, but is unlikely to reduce current driving distances, as five of the most recent leaders in driving distance on the PGA Tour used drivers less than 1.17 m in length [5].

Corresponding author email: psgfergu@uwaterloo.ca

The effect of CG depth and face bulge radius r_B on optimal drives was studied using the impact conditions of the 1.17 m driver presented earlier. For CG depths of 30, 35, and 40 mm, r_B was optimized so a mishit of 20 mm towards the heel of the clubface would land on the fairway center line. Fig. 1 plots the ball flight of both the center-hit and 20 mm heel mishit for each CG depth with the optimized r_B.

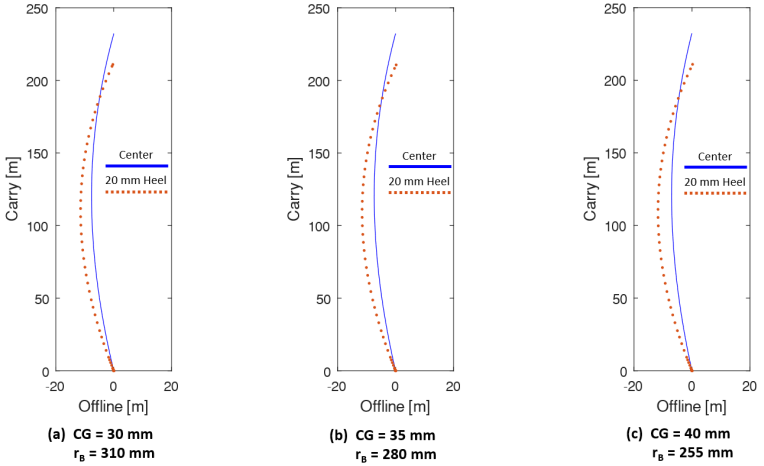

Fig. 1: Ball flights with optimal r_B for CG depths (a) 30 mm (b) 35 mm (c) 40 mm

Increasing CG depth required a smaller r_B to land on the center line – the additional sidespin imparted by increasing the CG depth needed to be offset by launching the ball further offline to ensure a center landing. Of note, the optimal center hit is not a straight shot because the model's biomechanics can produce more clubhead speed with a club path that is out-to-in, generating a slight fade shot shape. While these results can give a general indication of the optimal relationship between CG depth and bulge radius, the ideal combination of these parameters will vary from golfer to golfer depending on their clubhead delivery and mishit tendencies.

1. Stachura M "Golf's ruling bodies take next step in limiting driver length". Available online: golfdigest.com/story/driver-length-limit-usga-ra-news (accessed on 25 November 2021)
2. McNally W, McPhee J (2018) Dynamic Optimization of the Golf Swing Using a Six Degree-of-Freedom Biomechanical Model. *Proceedings* 2(6), 243.
3. Danaei B, McNally W, Henrikson E, McPhee J (2020) Adjusting a Momentum-Based Golf Clubhead-Ball Impact Model to Improve Accuracy. *Proceedings* 49(1), 47.
4. Ferguson S, McNally W, McPhee J (2022) Predicting the Flight of a Golf Ball: Comparing a Physics-Based Aerodynamic Model to a Neural Network. In Proceedings of the 14th Conf. of the ISEA.
5. Wall J "We got the exact specs for 5 PGA Tour bombers: Here's 1 thing they all have in common". Available online: golf.com/gear/drivers/driver-specs-pga-tour-driving-distance-rory-dustin-johnson-champ/ (accessed on 24 August 2021)

Corresponding author email: psgfergu@uwaterloo.ca