Towards a Biomechanical Understanding of Tempo in the Golf Swing

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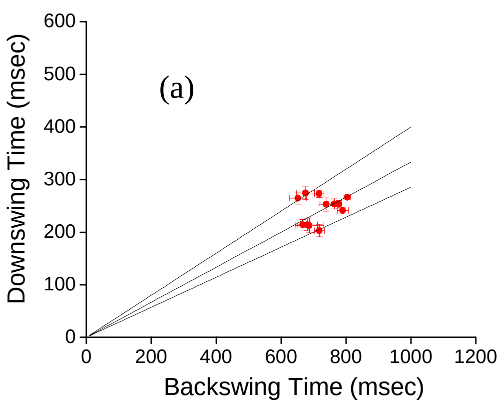
It is proposed that aspects of the tempo of the golf swing can be understood in terms of a biomechanical clock. This model explains several aspects of tempo in the golf swing; including total duration of the golf swing, the ratio of backswing to downswing time, and the relative insensitivity of tempo on the length of the golf shot. We demonstrate that this clock and the resulting tempo are defined by of the rotational inertia of the body/club system and the elastic properties of the body, yielding a system which can be modeled as a simple harmonic oscillator.

Tempo refers to the pace of the golf swing. It is can be characterized by measuring the duration of the backswing, T_b, and the duration of the downswing, T_d. While qualitative discussions of tempo are as old as the game itself, quantitative measurement of tempo has existed only for a couple of decades [*1*]. Recently, a study of the tempo of professional golfers was published in the book *Tour Tempo* [*2*] in which it was pointed out that the ratio of backswing to downswing time of professional golfers is of order three, $T_b/T_d \approx 3$. These measurements were made using the frame rate of standard video (i.e. 30 Hz frame rate) as the clock. The tempo of the majority of tour professionals studied in *Tour Tempo* is characterized by $T_b \approx 24$ frames and $T_d \approx 8$ frames. The ratio T_b/T_d for all players reported in the study covered the range from 21/7 to 30/10. Also pointed out in *Tour Tempo* is that the overall tempo of professional golfers is significantly faster than that of the average golfer and that the tempo does not change significantly with the length of the shot or the type of club.

In an attempt to more thoroughly characterize tempo, we have performed measurements on a wide variety of golfers, from tour professionals to the average weekend golfers, using electronics embedded in the shaft of the golf club. The details of this measurement system are described elsewhere [*3*]. In summary, motion sensing accelerometers and wireless communications electronics mounted in the shaft allow us to determine the start of the swing, the transition from backswing to downswing, and the point of impact. Sampling rates are of order 250 Hz, yielding eight times more detail than that obtained from conventional video.

Ten to twenty swings were recorded for each golfer as they hit a five iron. T_b and T_d are measured for each swing. Using the ensemble of swings, the average and standard deviation of T_b and T_d is calculated for each golfer. The standard deviation is used to characterize reproducibility. The results of these measurements are displayed in Figs. 1. The golfers are divided into three groups: a) playing professionals (n=12); b) teaching professionals and good amateur golfers (n=13); and c) all other golfers (n=18). Each data point represents the averaged result for a particular golfer. The standard deviations are indicated by error bars.



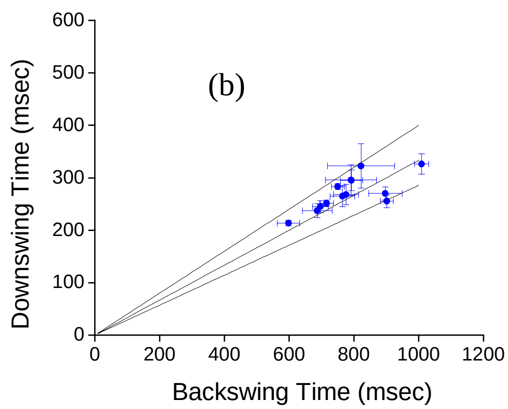
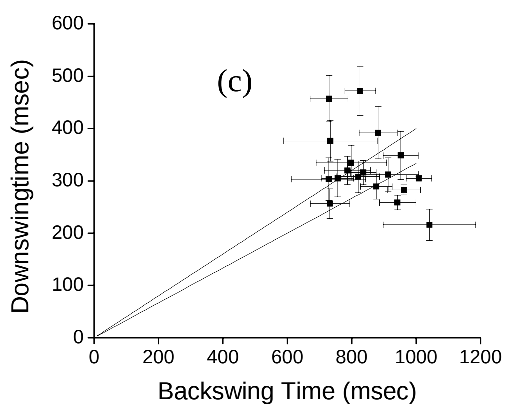


Fig. 1: A graphical representation of the tempo of the golf swing for (a) playing professionals, (b) teaching professionals and good amateurs, and (c) all other golfers. The abscissa is the duration of the backswing and the ordinate is the duration of the downswing. The lines indicate slopes of 2.5, 3.0 and 3.5. Each data point represents the mean of several swings of an individual golfer. The standard deviation of each measurement is indicated by the error bars.



The data for playing professionals is consistent with the data reported in *Tour Tempo*. The ratio T_b/T_d varies between 2.5 and 3.5, with the average being nearer to 3.0. Additionally, these golfers exhibit very small values of standard deviation relative to all other golfers, meaning that their swings are very reproducible. Note that the time of the backswing of the tour professionals all seem to cluster in the vicinity of $T_b \approx$ 0.7 – 0.8 sec, which corresponds to 21-24 frames per second of standard video, again consistent with the data presented in *Tour Tempo*.

The distributions in Fig 1(b) and Fig 1(c) are noticeably larger than that of Fig 1(a). In both cases, the average ratio T_b/T_d is centered at 3.0, but varies widely, much more so for the last group of golfers. As one might expect, the standard deviations measured for most other golfers are much larger than that of tour professionals. Additionally, the golf swings of the professional golfer are uniformly faster than that of the average golfer.

The following three aspects of the tempo of playing professionals suggest the workings of a biomechanical clock: 1) the fact that all playing professionals have roughly the same tempo, 2) the very small variance in tempo from swing to swing for individual playing professionals, and 3) the relative insensitivity of tempo to the length of the swing or the type of club. In this section we explore the plausibility that the simplest model of a clock, the simple harmonic oscillator, can be used to understand tempo in the golf swing of professional golfers.

The simple harmonic oscillator requires a mass and a spring, *i.e.* a restoring force. In this proposed model the mass is comprised of the torso, legs, arms, and club. The spring results from the "effective" elasticity of the biomechanical system, comprising the natural and trained response of the body. The importance of elasticity in animal movement has long been documented [*4*, *5*, *6*, *7*, *8*], and we propose it plays a central role in defining the tempo of the golf swing of professional golfers.