TORQUE-TO-SPIN EFFICIENCY OF PITCHES ANALYSED WITH A SMART BASEBALL

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Introduction: Sports balls are spun by applying a friction force (in addition to the normal force) to their surface, which produces a torque T_R. The T_R imparted accelerates the ball and thereby generates and increases its spin rate ω (angular velocity). Yet, not only T_R determines the magnitude of ω, but also how efficiently T_R is converted to ω. The efficiency decreases the greater the angle θ (normalised precession p_n, [1]) is between $\mathbf{T_R}$- and $\boldsymbol{\omega}$-vectors The greater θ, the more T_R is wasted for moving $\boldsymbol{\omega}$ into $\mathbf{T_R}$ (precession p). The aim of this paper is to investigate the torque-to-spin efficiency while pitching before releasing the ball.

Method: For determining ω, we used a smart baseball [2], a spin-off of a smart cricket ball [3], that measures ω at a sampling frequency of 815 Hz. From ω we calculated the following performance parameters (explained in detail in [4]) with the smart ball's software: angular acceleration α; resultant torque T_R and its two components, the spin torque T_s (= $\alpha\, I$, where I is the moment of inertia) and the precession torque T_p; power P; rotational energy; precession p (= $T_p/[\omega I]$; speed of moving $\boldsymbol{\omega}$-vector, ideally 0); normalised precession p_n (= $\theta = \sin^{-1}(p\,\omega I/T_R$; angle between $\mathbf{T_R}$- and $\boldsymbol{\omega}$-vectors, ideally 0°, worst case 90°); efficiency η (ratio of actual energy to ideal energy, where the latter results from the ideal case of $\theta_t = 0$); 'frequency' f (= $\alpha_{\max}/\omega_{\max}$). The more efficient a pitching type, the smaller are p, p_n, T_p, f, and the greater is η. In addition to the smart ball, we determined ω and the translational speed v of the ball with Mevo (FlightScope, Orlando, FL, USA), and benchmarked $\omega_{\text{smartball}}$ vs ω_{Mevo}. Four players pitched fastballs, curveballs, and sliders five times each. This research was granted Ethics approval by the Swinburne University Human Ethics Committee (no. 20191582-3216), and adhered to the Declaration of Helsinki, and informed consent was obtained.

Results and Discussion: ¼ of the ω_{Mevo} data were outliers and therefore inaccurate (Fig. 1a). The average data of the performance parameters are shown in Table 1. From the Kruskal-Wallis test, there was a statistical difference ($p<0.05$) between

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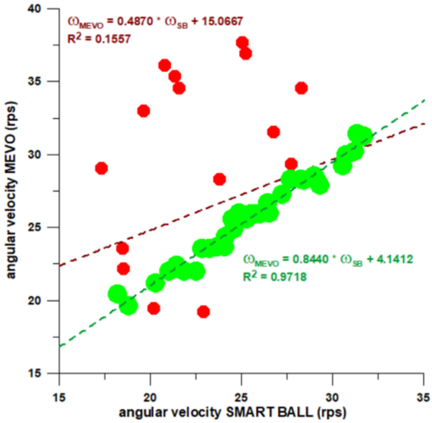
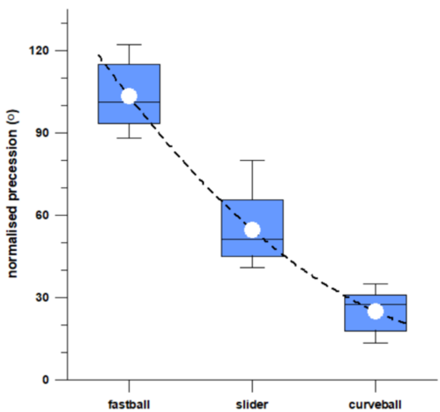
fastballs, sliders and curveballs in all parameters except for ω and P. The efficiencies η of slider and curveball were marginally indifferent in the post-hoc tests (p = 0.056). All five parameters (p, p_n, T_p, η, f) informing of the torque-to-speed efficiency showed the same pattern: best performance in the curve ball and worst in the fastball (Fig. 1b). This result matches the pattern seen in cricket ball deliveries: backspin deliveries (such as the fastball in baseball) are least efficient, topspin ones (such as the curveball) are most efficient, and sidespin ones (such as the slider) are characterised by intermediate efficiency [1, 4]. The outliers may be due to the Doppler radar not recording the spin rate consistently.



(a)



(b)

Fig. 1a: Correlation of angular velocities ω_{MEVO} vs ω_{SB} (outliers in red)

Fig. 1b: Normalised precession of three types of pitches (box plot and average)

Table 1: averages of performance parameters; FB = fast ball, SL = slider, CV = curveball

pitch	v (m s^{-1})	ω (rps)	T_R (Nm)	P (W)	p (rad s^{-1})	$p_n = \theta$ (°)	T_p (Nm)	η (%)	α/ω (s^{-1})
FB	34.58	24.83	0.459	31.01	108.5	103.4	0.390	18.85	29.32
SL	31.10	24.86	0.365	27.69	51.3	54.8	0.253	28.30	24.56
CB	26.21	23.55	0.277	23.38	20.7	25.0	0.123	33.56	23.05

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