Modeling Elbow Valgus Torque From Ball Weight With 381,946 Baseball Throws

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INTRODUCTION: The scalability and usability of inertial measurement units (IMU's) allows for biomechanical research to be conducted on datasets that are orders of magnitude larger than traditional motion-capture equipment allows for. IMU's also allow for capture of data in real-world settings rather than in a laboratory. From both a clinical rehabilitation and return-to-throwing perspective, there is a large need to better understand the effects of ball weight on elbow valgus torque.

PURPOSE: To develop a data-driven framework for the prediction of elbow valgus torque during specific weighted ball work.

METHODS: Data were mined from 20,000 motusTHROW users who wore a Motus IMU and sleeve (Rockville Centre, NY, USA) that measures peak elbow valgus torque during throwing. A total of 381,946 anonymized throws were mined with the tag of "Weighted Ball" which can be set in the motusTHROW mobile application. The user-input ball weight is used in the inverse dynamics formula to compute peak elbow valgus torque. Peak torque was normalized by player height and weight.

The 381,946 throws resulted in 18 different ball weight categories. The inclusion criteria of a ball weight category was to require 1000 or more throws tagged with the specified ball weight. A one-way ANOVA was performed to test for differences in elbow torque between ball weights with Tukey post-hoc tests used to for p-value calculation. The significance level was set at $p< 0.01$.

RESULTS: Of the total 153 ball weight relationships, only 7 combinations did not have statistically significant differences: A) 3.5-5.3-16 oz, B) 5-5.3 oz, C) 6-8 oz, D) 3-15.9 oz, E) 3-21 oz, F) 7-14-21 oz, and G) 14-21-32 oz ($p < 0.01$). The two highest elbow torques were associated with a 4 oz and 16 oz ball weight. As ball weight increased (up to 11 oz), elbow torque decreased. As ball weight increased from 11 to 16 oz, elbow torque began to increase to more elevated magnitudes, yet remained less than the 4.0 oz weighted ball torques.

CONCLUSION: 4.0 oz ball weights produce the highest elbow valgus torques. This is likely due to the arm being able to accelerate faster with less weight, which in turn results in larger kinetic impulses. Mid-range weighted balls (6-11 oz) generally produce lower elbow valgus torques, likely due to the arm accelerating less with heavier balls.

However, 16 oz weighted balls had the 2nd highest elbow torque, and was statistically equivalent to 3.5 and 5.3 oz baseballs ($p<0.01$). This may be due to increased arm speeds generated from under-load training, which carries over to heavier weighted baseballs. Caution should be used with 16 oz balls, and usage decisions should be determined in accordance with workload status and biomechanical analysis to prevent valgus overload and fatigue exposure.

Table 1. Mean (+/- Standard Deviation) of Elbow Valgus Torque with various weighted balls

Ball Weight (oz)	Elbow Valgus Torque (% BW*HT)	N	Significance
3.0	0.0231+/- (0.0107)	4,560	e,f
3.5	0.0266+/- (0.0083)	5,311	a
4.0	0.0276+/- (0.0109)	6,256	*
5.0	0.026+/- (0.009)	77,388	b
5.3	0.0263+/- (0.0085)	5,639	a,b
6.0	0.0241+/- (0.009)	33,031	d
7.0	0.0225+/- (0.0083)	51,113	g,h
7.9	0.0251+/- (0.0083)	9,576	*
8.0	0.0241+/- (0.0098)	4,193	d
9.0	0.0196+/- (0.0085)	46,547	*
11.0	0.0155+/- (0.0085)	23,484	*
14.0	0.0223+/- (0.0085)	3,053	g,h
15.9	0.0231+/- (0.01)	28,405	e
16.0	0.0268+/- (0.0114)	12,062	a
21.0	0.0224+/- (0.0092)	2,566	f,g,h
32.0	0.022+/- (0.0116)	19,686	h
35.3	0.0205+/- (0.01)	37,663	*
70.6	0.021+/- (0.0099)	11,413	*

Note: *significantly different from all ball weights. (a-g) are significantly different from all ball weights except between a) 3.5-5.3-16 oz, b) 5-5.3 oz, c) 6-8 oz, d) 3-15.9 oz, e) 3-21 oz, f) 7-14-21 oz, and g) 14-21-32 oz

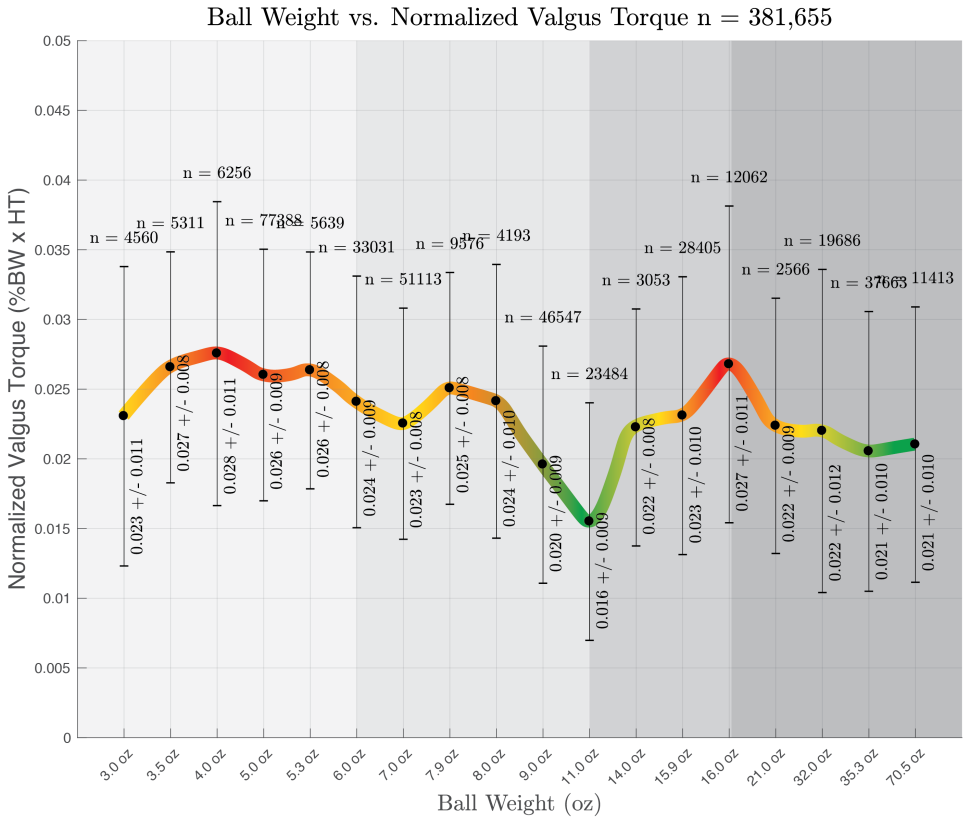

Figure 1 – Scatter plot (with standard deviation error bars) of ball weight versus peak elbow valgus torque.