AN ACCURACY-INTEGRATED METRIC FOR EVALUATING THROWING PERFORMANCE

Billy Lozowski[1], Gretchen Oliver[1]

[1] School of Kinesiology, Auburn University, Auburn AL, USA

The purpose of this study was to present a proof-of-concept for a novel Accuracy-Integrated Metric (AIM) to evaluate throwing performance. Ball velocity, displacement from target, and throw distance data were simulated for ten throws, and an AIM score calculated for each. Throws were ranked per conventional evaluation methods (by ball velocity), and by AIM score. When ranked on ball velocity, throw 7 ranked highest (36.0 m.s^{-1}); however, it scored lowest with AIM (10.2) owing to a large displacement value. Discrepancies in these rankings highlight the limitations of relying solely on one aspect of performance when evaluating throwing. By considering ball velocity and accuracy together, AIM provides a more objective way to assess throwing performance which it is hoped will facilitate greater in-depth analyses of throwing biomechanics, and the aspects related to performance.

KEYWORDS: integration model, overarm throw, assessment

INTRODUCTION: The overarm throw is one of the most researched motions within the fields of biomechanics and motor learning. For nearly a century, it has been the subject of countless research studies, identifying many of the mechanisms of both injury and performance. In terms of performance, ball velocity and accuracy are generally the two main components that combine to determine whether a throw is successful (Freeston et al., 2007). It is perhaps unsurprising then, that a considerable quantity of the literature has sought to determine the factors related to improving each. To date, several kinetic and kinematic parameters have been linked to ball velocity (Fortenbaugh et al., 2009; Werner et al., 2008), whilst central nervous function (Hore et al., 1995; Hore & Watts, 2005) and variability in trunk and shoulder kinematics (Glanzer et al., 2021) have been linked to accuracy and endpoint location consistency.

This information has been crucial in understanding how throwing mechanics influence performance; however, one considerable drawback remains. Ball velocity and accuracy are typically treated as separate entities in the throwing literature. Limited work exists that considers both concurrently. Where throwing research has considered ball velocity and accuracy together, it has investigated the principle of the speed-accuracy trade-off (Freeston et al., 2007; Liang et al., 2023; Venkadesan & Mahadevan, 2017). Although this has facilitated an understanding of the interaction between ball velocity and accuracy (accuracy decreases as velocity increases), it lacks a suitable way to quantify throwing performance due to the absolute magnitudes of each not being considered. Only ball velocity is reported in magnitudes, whereas accuracy is usually defined in categorical terms.

Since throwing performance requires a combination of ball velocity and accuracy, and these two measures cannot currently be combined appropriately, truly understanding how biomechanics influence performance is not currently possible. There is a need, therefore, to integrate the ball velocity and accuracy into a single metric of performance. This study attempts to overcome this problem by proposing a novel metric for evaluating throwing performance. The Accuracy-Integration Model considers magnitudes of ball velocity and accuracy concurrently. By using this new Accuracy-Integrated Metric (AIM), a more objective assessment of throwing performance will be facilitated, allowing for a greater in-depth analyses of throwing biomechanics.

METHODS: For this proof-of-concept, three ball metrics were simulated for ten trials: ball velocity, distance, and displacement. Values for all three were constrained within certain parameters to

ensure they were representative of those expected for various overarm throws. Ball velocity values ranged between 26 and 36m.s^{-1} to align them with values reported in the literature (Ahmed et al., 2021; Cook & Strike, 2000; Werner et al., 2008). Throw distances ranged from 7.5 to 60m to demonstrate the benefits of AIM over various distances. It was reasoned that the shorter of these distances was an appropriate threshold where the likely strategy to execute the throw would be overarm. Finally, displacement (absolute error relative to an intended location; Kawamura et al., 2017) values ranged from 0 to 2.5m. Previously, literature has used a 1m area around the target for throws up to 40m (Cook et al., 2000); however, the decision to extend this up to 2.5m was based on the assumption that at greater distances, it is unlikely throws will be consistently within 1m of their intended target.
These three metrics were then used to calculate an AIM score for each throw using the following formula:

$$\frac{vd}{10^s}$$

where *v* is ball velocity at ball release, *d* is the distance of the throw from its release point to target, and *s* is the triangulated displacement of the ball's location from its intended target (Figure 1). Using displacement as an exponent of 10 on the bottom half of this equation ensures there is always a denominator value to divide the top portion by (since any number to the power of 0 equals 1). The use of '10' serves as a scaling factor to ensure AIM scores are reasonable for interpretation.
In this configuration:

1. Faster throws score higher if throw distance and displacement are maintained.
2. Longer throws are rewarded if velocity and displacement are maintained.
3. More accurate throws are rewarded when velocity and distance remain the same.

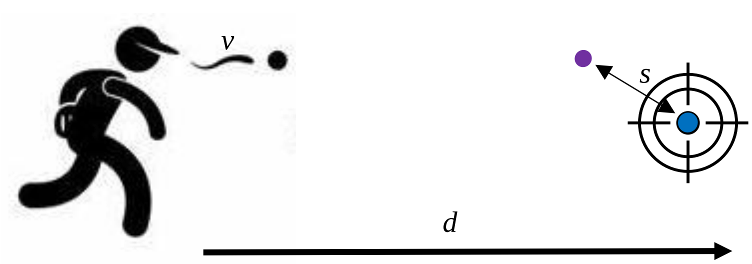

Figure 1. Illustration of AIM variables. Blue dot = intended location, purple dot = actual location.

RESULTS & DISCUSSION: Simulated throwing data are presented in Table 1. When ranking per conventional methods (ball velocity), throw 7 is ranked highest (v = 36.0m.s^{-1}) whilst throw 10 is ranked lowest (v = 26.3m.s^{-1}). However, when using AIM, throw 7 ranks lowest (AIM = 10.2), which appears to be attributable to it being the least accurate of all simulated attempts. This is seemingly confirmed when comparing it to throw number 1, which scores higher with AIM (AIM = 61.9) despite having similar velocity and throw distance values. The smaller displacement value for throw 1 results in a larger denominator for the AIM equation and, consequently, a smaller AIM score.

Table 1. Simulated throwing data, AIM scores, and ranks by ball velocity and AIM.

					Rank	
Throw #	*v*	*d*	*s*	AIM	Velocity	AIM
1	35.9	58.5	1.53	61.9	2	6
2	29.4	12.8	0.54	108.2	8	3
3	33.5	20.3	0.84	98.5	6	4
4	34.2	45.1	1.56	42.5	4	7
5	27.6	8.9	0.35	109.6	9	1
6	31.8	25.7	0.95	91.6	7	5
7	36.0	55.2	2.29	10.2	1	10
8	34.9	36.0	1.61	30.8	3	8
9	34.1	60.0	2.12	15.5	5	9
10	26.3	7.9	0.28	109.0	10	2

Note: v = ball velocity ($m.s^{-1}$); d = distance (m); s = displacement (m). Displacement is the absolute error of the ball from an intended target location (Kawamura et al., 2017).

When ranked by AIM score, throw 5 ranks highest (AIM = 109.6). Despite ranking 9th in terms of velocity (v = 27.6$m.s^{-1}$), it was rewarded for its accuracy (s = 0.35m). The same is true for throw 10, which ranked second (AIM = 109.0). At first glance it may appear that AIM weights accuracy more than velocity, however, it is clear that this is not the case when we consider throws 2, 5 & 10. Throw 5 was faster compared to throw 10 (27.6$m.s^{-1}$ vs. 26.3$m.s^{-1}$), but it was also further from the target (s = 0.35m vs. s = 0.28m). Throw 5 was subsequently rewarded for having greater velocity with a higher AIM score, even though it was less accurate. Throw 2 was less accurate than both throw 5 and throw 10, yet it scored similarly in terms of AIM (AIM = 108.2). The additional 1.8$m.s^{-1}$ of ball velocity compared to throw 5 and 3.1$m.s^{-1}$ compared to throw 10 subsequently results in throw 2 being considered comparable in terms of performance to these more accurate attempts due to its greater release velocity.

These results demonstrate that ball velocity is not always the most important aspect of a throw. Accuracy is also a key determinant in whether an attempt is successful or not, and should therefore be considered concurrently with ball velocity. Though this is not the first study to use such an approach (Freeston et al., 2007; Liang et al., 2023; Venkadesan et al., 2017), it differs from previous work by acknowledging the continuous nature of both performance measures. Magnitudes of accuracy (absolute error of the ball from an intended target location) have been used in conjunction with ball velocity, allowing for their full integration into a single measure of performance. Since the goal of almost all sports to be successful, using a single performance metric allows for an objective assessment on a throw-by-throw basis. This offers a more pragmatic approach for the identification of biomechanical factors that are most closely related to performance, rather than individual aspects of it.

CONCLUSION: This paper has highlighted the need to consider multiple aspects when evaluating throwing performance, and has proposed an alternative method in AIM to overcome current shortcomings. AIM allows for a more holistic evaluation of performance as it considers magnitudes of velocity *and* accuracy concurrently (with the addition of throw distance to suit various throwing skills). Providing the throw's velocity, its length, and an individual's intended location are known, AIM allows every throw to be quantitatively assessed and compared. AIM score can then be used to compare players against themselves in training or game environments, or to one another to determine who may or may not be most effective at a given throwing task. This may benefit training practices and talent identification, whilst serving as an approach to facilitate a deeper understanding of throwing biomechanics and performance.

REFERENCES

Ahmed, S., Brown, J., & Gray, J. (2021). Predictors of throwing performance in amateur male cricketers: A musculoskeletal approach. *European Journal of Sport Science, 21*(8), 1119-1128.

Cook, D. P., & Strike, S. C. (2000). Throwing in cricket. *Journal of Sports Sciences, 18*(12), 965-973.

Fortenbaugh, D., Fleisig, G. S., & Andrews, J. R. (2009). Baseball pitching biomechanics in relation to injury risk and performance. *Sports Health*, *1*(4), 314-320.

Freeston, J., Ferdinands, R., & Rooney, K. (2007). Throwing velocity and accuracy in elite and sub-elite cricket players: A descriptive study. *European Journal of Sport Science*, *7*(4), 231-237.

Glanzer, J. A., Diffendaffer, A. Z., Slowik, J. S., Drogosz, M., Lo, N. J., & Fleisig, G. S. (2021). The relationship between variability in baseball pitching kinematics and consistency in pitch location. *Sports Biomechanics*, *20*(7), 879-886.

Hore, J., Watts, S., Martin, J., & Miller, B. (1995). Timing of finger opening and ball release in fast and accurate overarm throws. *Experimental Brain Research*, *103*, 277-286.

Hore, J., & Watts, S. (2005). Timing finger opening in overarm throwing based on a spatial representation of hand path. *Journal of Neurophysiology*, *93*(6), 3189-3199.

Kawamura, K., Shinya, M., Kobayashi, H., Obata, H., Kuwata, M., & Nakazawa, K. (2017). Baseball pitching accuracy: an examination of various parameters when evaluating pitch locations. *Sports Biomechanics*, *16*(3), 399-410.

Liang, Y., Kamiel-Skeete, A., Pettitt, A., & Hiley, M. J. (2023). Where in a time constrained throwing task is the speed-accuracy trade-off?. *Journal of Sports Sciences*, 1-6.

Venkadesan, M., & Mahadevan, L. (2017). Optimal strategies for throwing accurately. *Royal Society Open Science*, *4*(4), 170136.

Werner, S. L., Suri, M., Guido Jr, J. A., Meister, K., & Jones, D. G. (2008). Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers. *Journal of Shoulder and Elbow Surgery, 17*(6), 905-908.