FRONT FOOT SLIDE VARIABILITY AND ITS RELATION TO TENPIN BOWLING PERFORMANCE

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INTRODUCTION: In tenpin bowling, bowlers try to knock down as many pins as possible with the allotted number of tries. In the modern power game, they achieve this by generating a lot of momentum using heavy balls released accurately at great velocities (Strickland, 1996). It must be done consistently over many tries. Although accuracy of the front foot slide during the delivery phase seems less relevant compared to the accuracy of the ball release, its consistency is still paramount. The ability to slide the front foot consistently presumably enables the bowler to have a predictable stable base to deliver the ball more accurately. Variability in performing sports skills has been studied in various disciplines such as javelin and basketball (Bartlett, 2008), but no published data is available on tenpin bowling. In fact, published work on tenpin bowling is rather scarce; the only recent study was by Chu and colleagues (2002) which compared a number of kinematic variables in the sagittal plane between male and female bowlers. The purpose of this study was to look at how variability of the front foot slide was related to average bowling score (B_{ave}) and ball release velocity (BR_{vel}). In addition, the variability of the foot kinematics between elite and amateur bowlers was also compared.

METHODS: Participants were assigned into two groups based on their B_{ave} over 3 tournaments, with those averaging above 200 pin falls placed in the elite group. There were 18 elite (M=10, F=8; B_{ave} 213.2±6.80) and 12 amateur bowlers (M=7, F=5; B_{ave} 181.3±9.36). Foot kinematic data were derived from Kwon3D motion analysis system, while BR_{vel} was measured by timing gates. Four Basler (100Hz) cameras were used for motion capture, which was carried out at the bowling alley. The participants aimed for a strike at each delivery, meaning that pins were reset after each trial irrespective of whether there were any pins left standing. There were 7 trials and bowlers were instructed to use similar delivery methods for every trial. However, only trials 3 to 6 were used in the analysis. Reflective markers (15mm) were placed at the front tip of the bowling shoe and under the heel counter, the midpoint between the two markers was taken as the foot position. Time series data were normalized from top of back swing (TBS) to the top of follow through (TOF). The following discrete and continuous Foot Position (FP) variables were determined; Anterio-Posterior (AP) and Medio-Lateral (ML) position, AP velocity and acceleration. The mean Standard Deviation (SD) of the trials were used as the variability indicator of the front foot slide, while mean peak values were used for velocity and acceleration variables. Independent samples t-test and Pearson Product Moment Correlation were used to compare groups and look at relationships, respectively. Significance level was set at $p<0.05$.

RESULTS: The results relating to the group comparisons and relationships of the front foot slide variability is summarised in Table 1. Meanwhile, in terms of the relationship between BR_{vel} with foot velocity and acceleration; BR_{vel} was significantly correlated with peak foot velocity ($r = 0.52$), peak acceleration ($r = 0.39$) and peak deceleration ($r = -0.48$). Unsurprisingly, BR_{vel} was significantly correlated to the B_{ave} ($r = 0.59$).

Table 1

	Correlation	
Variable	**Mean SD**	**Coefficient**
AP foot position at FS	0.065	▲r = 0.46
AP foot position averaged	0.415	+r = 0.53
ML foot position at FS	0.015	▲r = -0.46
ML foot position averaged	0.016	▲r = -0.40

▲Significant correlation to bowling average
+Significant correlation to ball release velocity

	Group Comparison	
Group	**Mean SD**	**t-value**
Elite	0.736	t_{28} = 2.48*
Amateur	0.525	
Elite	0.132	t_{28} = -0.96
Amateur	0.150	
Elite	0.013	t_{28} = -
Amateur	0.019	2.88*
Elite	0.014	t_{28} = -
Amateur	0.019	2.33*

*Significant difference

DISCUSSION: In terms of B_{ave}, it seems that the consistency of left to right position of the front foot plays a significant role, with results showing that the lower variability in ML position at FS prior to the slide correlated with better bowling scores. This is supported by the fact that those who had followed a more consistent ML foot path throughout delivery had also shown better B_{ave}. Furthermore, the elite group were more consistent in ML position at FS and had less variability of ML position throughout. Interestingly though, higher variability in AP foot position at FS seem to relate to better B_{ave}. This could possibly be explained by the results of the correlation figures of BR_{vel}. Higher variability of AP foot position throughout delivery was related to higher BR_{vel}. But, taking into consideration that higher BR_{vel} also relates to higher peak foot velocity, higher acceleration and deceleration of the foot, the results are somewhat expected. As it is necessary for bowlers to stop their slide before the foul line, it is possible that a bowler moving at greater speeds will invariably constantly need to adjust their AP foot position in order not to pass the line. This is commonly referred to as the speed-accuracy trade-off (Schmidt et. al., 1979); trying to perform a skill quickly tends to lead to less accuracy and less consistency. Even though moving at higher velocities can lead to higher AP variability, good bowlers still seem keen to achieve higher momentum, preferring to just concentrate in minimising ML variability. The importance of BR_{vel} is highlighted by its significant correlation to better B_{ave} and supports the notion that modern bowling is very much a power game.

CONCLUSION: Accuracy and consistency have been acknowledged as important factors in tenpin bowling, but its specific application to training is rather limited. Results of this study indicate that consistency of side to side foot path during slide and foot placement at the start of the slide is important to achieving better bowling scores. In terms of practice, in addition to the already available markers at the front end of lanes, coaches may want to consider leaving markers or drawing explicit lines on the lanes during training to help achieve more consistent foot positions during the slide. Consequently, front to back position of the sliding foot should be expected to vary as the bowlers try to adjust their body segments to stop before the foul line whilst trying to attain greater ball release velocities.

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