VARIABILITY OF RELEASE PARAMETERS IN BASKETBALL FREE-THROW

Nobuyasu Nakano[1], Senshi Fukashiro[1] and Shinsuke Yoshioka[1]

Graduate School of Arts and Science, University of Tokyo, Tokyo, Japan[1]

This study aimed to clarify what kind of variability of release parameters was associated with shot accuracy in basketball free-throw. Eight male right-handed basketball players in a college team participated in this study. Participants made 50 shots from the free-throw line after warm-up. A 16-camera motion capture system recorded the coordinates of the reflective markers attached on the participants' bodies and the ball. The ball release parameters (i.e. release speed, angle and position) were calculated for the ball at the time of release. TNC-analysis that quantifies tolerance, noise, and covariation cost of a performance and a correlation analysis were used to analyse the variability of release parameters. Our results showed that the value of C-cost is smaller for the participant whose shot probability of success was high. Our results suggest that learning various patterns of success in training may be efficient for improvement in free-throw.

KEYWORDS: free-throw, release parameter, variability.

INTRODUCTION: A decrease of error and variability in goal-directed movements is recognized to improve the performance of sports such as basketball shooting or darts throwing. However, even for simple tasks that repeat the same movement under the same conditions, human movement always involves variability and is not constant (Faisal et al., 2008). Understanding the strategy of motor control that minimizes the variability of movements while dealing with such problems can improve the performance of sports.

Basketball shooting, especially free-throw, is a typical sports movement in which reducing variability of movements improves the performance (Tran & Silverberg, 2008). Previous studies on basketball shooting can be categorized into two types: one examined ball parameter and the other examined the joint parameter of human body. Several studies investigated the joint coordination and variability of the arm in basketball shooting using dynamical systems approach (Button et al., 2003; Robins et al., 2006; Mullineaux & Uhl, 2010). However, it is still unclear how players control the release parameters to reduce variability of the results in basketball shooting.

Recent studies developed variability analysis such as randomization and TNC-analysis and suggested that exploiting the redundancy (or abundance) of variables helps to reduce the variability of performance (Kudo et al., 2000; Cohen & Sternad, 2009). TNC-analysis quantifies Tolerance, Noise, and Covariation cost of a performance (Cohen & Sternad, 2009; Sternad et al., 2011) Since these studies focused on the process of learning of new motor task, little is known about how experts coordinate the redundant variables in movements acquired through long-term practice such as a sports movement. Using such concepts of analysis, the characteristic of the variability of the release parameters in free-throw can be identified.

The aim of this study was to clarify what kind of variability of release parameters was associated with shot accuracy in basketball free-throw.

METHODS: Eight male right-handed basketball players in college team participated in this study. The mean age, height, body mass, and free-throw shot probability of success of participants were 19.4 ± 1.1 years, 176 ± 8 cm, 70.5 ± 4.3 kg, and 65 ± 15 %, respectively. The participants provided written informed consent prior to the commencement of the present study, and the experimental procedure used in this study was approved by the Ethics Committee of the Graduate School of Arts and Sciences of the University of Tokyo.

Participants made 50 shots from the free-throw line after a warm-up shooting for 10-20 min as they liked to do. A total of 26, 4, and 6 spherical reflective markers were attached onto the body landmarks, the back board of goal and the ball being thrown, respectively. A 16-camera motion capture system (Motion Analysis Corp, Santa Rosa, CA, USA) was used to record the coordinates of the reflective markers attached on the participants' bodies and the ball at a sampling rate of 200 Hz. The experimental setup is shown in Figure 1a. The raw kinematic data were smoothed using a zero-lag fourth order Butterworth low-pass filter. The cut-off frequency of the filter was determined using a residual analysis (Winter, 2009), and its range was 5-20 Hz.

The centre position of the basketball was calculated using the coordinates of markers attached onto the ball by using least-square method. Ball release time was defined as the last time when the distance between the centre of the ball and the marker of the right fingertip became a local minimum. The ball release parameters (i.e. release speed, angle and position) were defined from the centre of ball at the time of release. To analyse the variability of release parameters, TNC-analysis that allows quantitative analysis of three components of variability: *Tolerance, Noise, Covariation* (Cohen & Sternad, 2009; Sternad et al., 2011) was used in this study.

TNC-analysis is based on the two-level description of the task; it presents a framework for examining the relation between variability in *execution* and *result*. In this free-throw task, the execution variables are the ball release parameters (speed, angle, and position) and the result variable is the distance between the centre of the hoop and the position of ball arrival. The position of ball arrival was defined by the equation below.

$$Y_a = y_0 + \frac{V_0^2 sin2\theta}{2g}\left(1 + \sqrt{1 - \frac{2g(Z_h - z_0)}{(V_0 sin\theta)^2}}\right)$$

Where, Z_h is the height of the hoop (3.05 m), and g is the gravitational acceleration 9.81 m/s^2. The effect of air force was assumed to be small enough to be regarded as zero. Then, the function to calculate the result variable from the execution variables (***E***) was defined by the equation below.

$$R = R(\boldsymbol{E}) = |Y_a - D|$$

The definitions of these variables are described in Figure 1b.

(a)

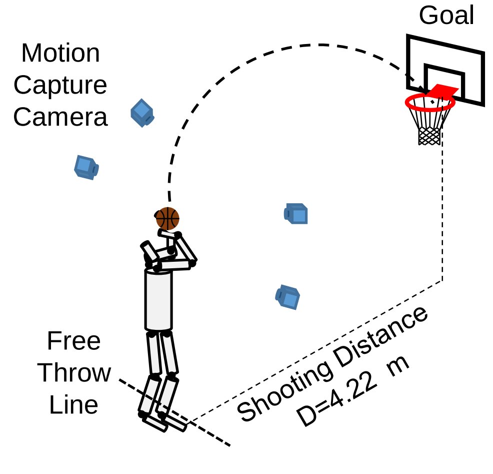

Figure 1a. Experimental Setup

(b)

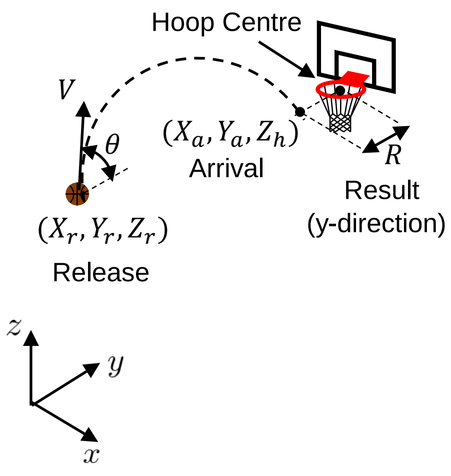

Figure 1b. Definition of variables

It should be noted that TNC-analysis used in this study was almost the same as the original one (Cohen & Sternad, 2009), but the method of optimization calculation to minimize the cost function was modified to "genetic algorithm" (Whitley, 1994).

For each set of 50 trials, the mean result determined from all 50 trials was calculated. For the calculation of each component, the data were transformed in a specific way to create another set with optimal results in terms of one component while the other features of the data set remained unchanged. The mean result for this optimized data set was calculated. The algebraic difference between the mean result from the actual data set and the mean result from the optimized data set was defined as the cost of the specific component by the equation below.

$$\text{X-cost} = \overline{R\left(\boldsymbol{E}_{actual}^{\text{X-cost}}\right)} - \overline{R\left(\boldsymbol{E}_{optimized}^{\text{X-cost}}\right)}$$

T-, N-, and C-cost express the difference between actual and optimized data set in terms of the "location", "size", and "orientation" of distribution of execution variables, as schematically described in Figure 2. The detail of the calculations of T-, N-, and C-cost was described in the previous study (Cohen & Sternad, 2009).

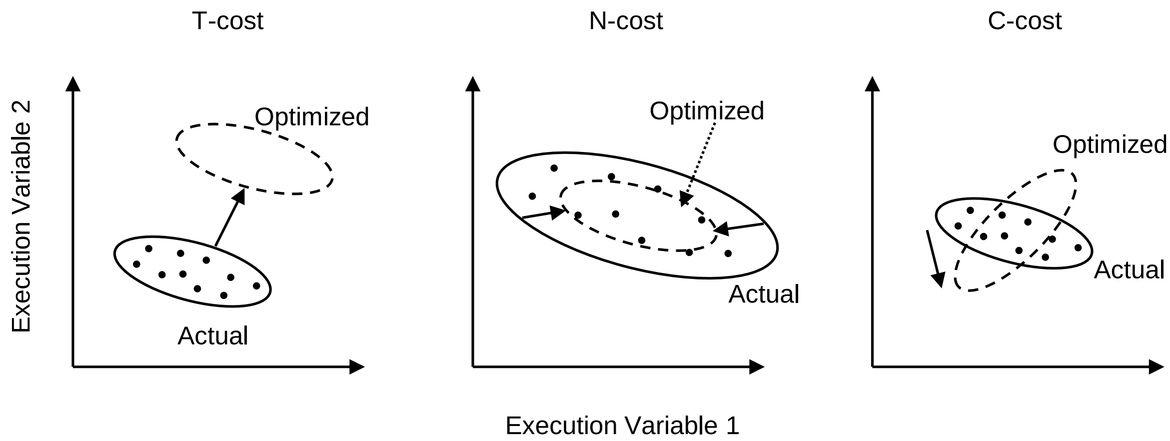

Figure 2. Schematic description of distribution of execution variables when calculating each cost

RESULTS: The relationships between the shot probability of success and each cost of all participants were shown in Figure 3. The C-cost was found to have strong negative correlation with the shot probability of success (r = -0.80, p = 0.017). The T-cost and the N-cost did not have the significant correlation with the shot probability of success.

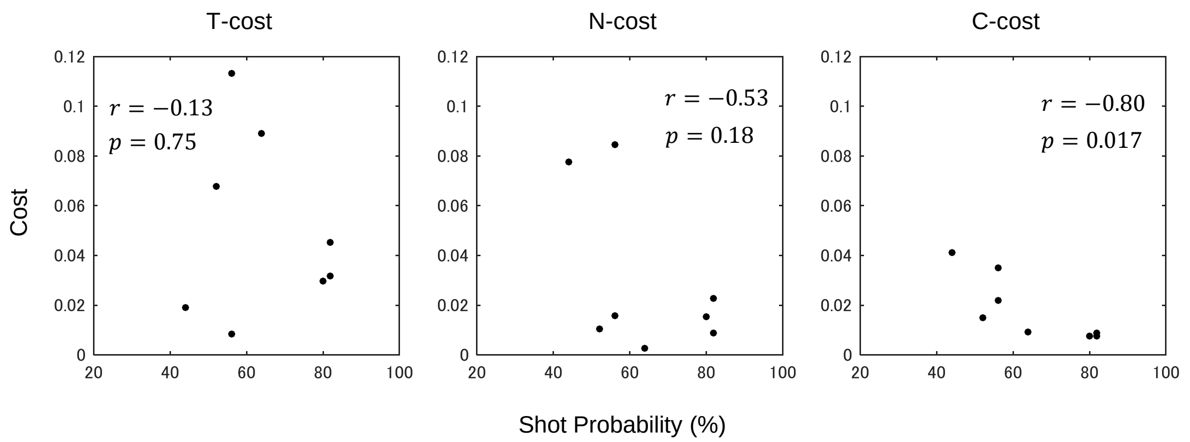

Figure 3. Relationship between shot probability and TNC-cost of all participants

DISCUSSION: The aim of this study is to clarify what kind of variability of release parameters is associated with the shot accuracy in basketball free-throw.

The C-cost was found to have strong negative correlation with the shot probability of success; this indicated that the value of C-cost was smaller for the participant whose shot probability of success was high. That is, skilled participants could coordinate the release parameters between trials (Figure 3). In darts throwing task, the skilled darts throwers achieved better index of covariation of release parameters than non-skilled throwers (Muller

& Loosch, 1999). Our finding is in line with the previous studies, although previous studies used slightly different methods to quantify the covariation.

The levels of the participants in this study are about the same level because they belong to the same team. The structure of the variability for more skilled players remain unclear. Nasu & Matsuo (2014) reported that two types of skilled participants were observed in throwing darts; one group utilized the compensatory coordination by covariation and the other group did not do so (Nasu & Matsuo, 2014). More skilled basketball players may have the different covariation pattern of release parameters in free-throw shooting.

T-cost was found not to correlate with the shot probability of success. However, T-cost was found to be greatly different among participants (Figure 3). The amount of T-cost expresses the cost of not using the best strategy to choose the release parameters. In the early stage of motor learning, performers search for a strategy of execution variables and discover the solution to succeed the motor task, thus T-cost drops (improved) rapidly (Muller & Sternad, 2004; Cohen & Sternad, 2009). It is possible that the strategy of execution variables of the participants whose T-costs were high had converged to sub-optimal solution; that is, those participants have acquired the non-optimal strategy with respect to the choice of release parameters. Teaching such players the better strategy of execution variables may improve their shot probability of success of free-throw.

It is necessary to pay attention to the calculation method for the interpretation of the value of N-cost. N cost was found to be higher for the participants whose T-costs were low, and lower for the participants whose T-costs were high (Figure 3). Since this is the problem of the analysis, the method to quantify or compare the noise component should be improved.

CONCLUSION: Skilled participants coordinated the release parameters between trials as evident by the low covariation cost. Further research is required to determine if learning various patterns of success in training may be efficient for improvement in free-throw shooting.

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