LOWER LIMB STABILIZATION STRATEGIES OF DART ATHLETES AT DIFFERENT LEVELS

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The purpose of the study was to understand lower limb stabilization strategies during the acceleration phase of dart throwing in athletes at different levels. Multi-Axis Force Plates and 3D Motion Capture were adopted to collect data. Six male darts athletes, including three elite athletes and three sub elite athletes, throw darts to hit Bull's Eye abiding the rules of the World Darts Federation. The study shows that during acceleration phase, the ground reaction force of elite athletes changes substantially, while the change of ground reaction force of sub elite athletes was relatively small. Significant difference of the change in the front foot ground reaction force (GRF) on a vertical axis is reached ($p<0.05$). The cause may be because the elite players use greater GRF transition from rear foot and front foot than sub elite players. On the contrast, sub elite athletes are still in the stage of integration, thus lower limb movement is minimized in order to stabilize the throw.

KEYWORDS: ground reaction force, precision sports, bull's eye

INTRODUCTION: Darts Sport has been flourishing in recent years. A growing number of people are joining the sport and various scales of competition are often held in various regions. 01 game is a common dart competition style that includes 301, 501, 701, etc. The game is to start with a set number of points, and each players have three darts in hand in each round. As the starting points are being reduced throughout the game, the first player who lowers the point to 0 wins.

There are several common postures of dart-throwing, including Frontal, Basic and Sideways, which are all standing postures. Therefore, elite athletes are often required to have excellent control of their lower limbs.

Upon examination of the throwing motion, it can be found that most of the actions are generated by upper limbs, while the lower limbs do not shift much. However, a slight weight shift is observed during the throwing process. By measuring through podometric plateform, it becomes apparent that the force shifts from the rear foot to the front foot (Vasiljev et al., 2017), which suggests that the force of lower limbs toward the ground does change when throwing. Moreover, the shift of GRF may important for throwing sports (Endo & Miyanishi, 2014).

Therefore, the purpose of this study is to explore the changes of the ground reaction force of lower limbs of players at different levels, as well as exploring control strategies of lower limb movement in precision throwing.

Methodology: Six male darts athletes were participated in the study (mean ± SD: height 1.73 ± 0.05 m; body mass 81.6 ± 22 kg; Phoenix Rating elite 20.6 ± 3.0 / sub elite 14 ± 2.8), including three elite athletes and three sub elite athletes, recruited by the Chinese Taipei Darts Federation. According to the Phoenix Rating, Rating 19 and above is considered as elite athlete, while Rating between 10 to 18 is considered as sub elite athlete. The definition of Rating 19 is finishing a 105 game within 15 throws.

The laboratory and the equipment were provided by the Chinese Taipei Darts Federation, and a special training dart board was used in the experiment. According to the rules of the World Darts Federation, dartboard height from the floor to the center of the Bull's Eye is 1.73 meters, and the horizontal distance from the Oche to the dartboard is 2.37 meters (Figure 1). Two six-axis force plates (Advanced Management Technology Inc., VA, USA) were adopted to collect ground reaction force and component force of the front feet and the rear feet, which the forces are aligning with anteroposterior (AP), mediolateral (ML), and vertical (Vert) axis of the space respectively. Extract frequency was set at 1000Hz. To identify the acceleration phase, several reflective balls for capturing motion data using 3D Motion Capture (Motion Analysis Corporation, Santa Rosa, California) were attached to the participants' throwing thumb, wrist, elbow, and acromion. The shooting sampling frequency was set at 250Hz to locate the acceleration phase. The shooting sampling frequency was set at 250Hz to locate the acceleration phase. The definition of the acceleration phase is the period of time that from elbow flexing to minimum angle to releasing the dart. Participants have fifteen throwing trials, and the electronic soft tip dart board judges the effectiveness of hit of Bull's Eye. After collecting the data of six players' three hits of Bull's Eye, the independent sample T-test is utilized to show the average ± standard deviation of the parameters.

RESULTS: As it is shown in Figure 2, the changes of ground reaction force of both front foot and rear foot in elite athletes is much higher than sub elite athletes. When the athletes accelerate to release the dart, the Vert-axis force of the rear foot gradually decreases while the front foot started to apply more force. It can be determined that the movement strategy of the lower limbs is to shift body weight from the rear foot to the front foot during throwing process. At the same time, a force similar to braking force (see AP-axis diagram in Figure 2), which

opposes to the force forward, is generated by the front foot of athletes. Change in value is found in Table1. However, the significant difference (p=0.0436, Elite group mean ± SD = 0.8325 ± 0.2442; Sub elite group mean ± SD = 0.34168 ± 0.15982) can only be reached on the front foot of F1(Vert) in both elite athletes and sub elite athletes.

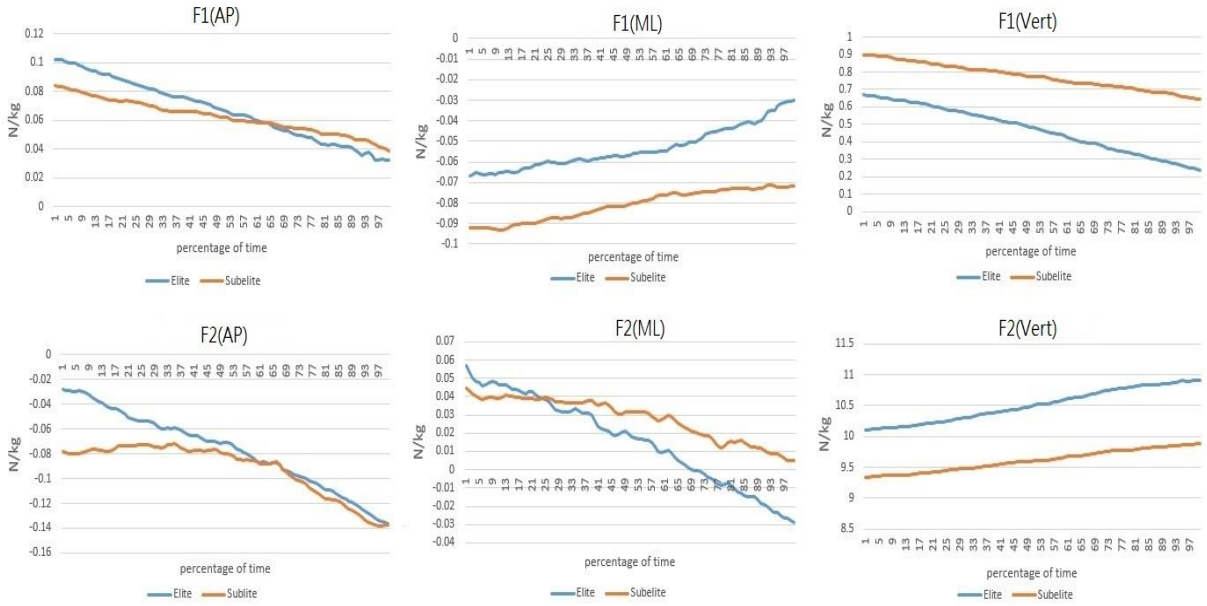

Figure 2: The relation between the ground reaction force (N/kg) and the percentage time of the acceleration phase for two groups of different level players. F1: rear foot, F2: front foot. Anteroposterior-axis (AP): Front: "+" / Back "– "; Mediolateral-axis (ML): Left: "+" / Right "– "; Vertical-axis (Vert): Up: "+" / Down "– ".

	Elite		Sub elite			
	mean	SD	mean	SD	t	p
F1(AP)	0.07218	0.00739	0.05622	0.03207	0.8398	0.4483
F1(ML)	0.04252	0.01465	0.02342	0.00496	2.139	0.0992
F1(Vert)	0.43108	0.183	0.29803	0.18579	0.8837	0.4268
F2(AP)	0.12055	0.12078	0.06087	0.01648	0.8479	0.4443
F2(ML)	0.08682	0.0702	0.03198	0.01123	1.336	0.2524
F3(Vert)	0.8325	0.2442	0.34168	0.15982	2.913	0.0436*

Table1: rate of change in GRF, standard deviation, t-value and p-value of ground reaction force.

DISCUSSION: It is observed in the study that during acceleration phase of throwing darts, the change of the ground reaction force in elite athletes is significantly higher than in sub elite athletes, which is different from the widely accepted consensus that less weight shift leads to better performance in precision sports. In research of Endo and Miyanish in 2014, the researchers had compared the dart-shooting technique of competitive athletes and

recreational players. The result showed that competitive athletes threw dart with their weight lining on the front foot whereas recreational players put two thirds of body weight on the rear foot and shift the weight from the rear foot to the front foot when throwing (Endo & Miyanishi, 2014). Furthermore, Mononen (2017) had discovered that highly skilled rifle shooters are shown to have relatively little postural sway when shooting with standing posture (Niinimaa & McAvoy, 1983; Aalto et al., 1990).

In this study, we found contrasting results. More change of ground reaction force is observed in elite athletes than in sub elite athletes during acceleration phase. From stages of learning model by Fitts and Posner (1967). It is argued that in the learning stage of dart throwing technique, self-implication thinking and motion of the body occurs simultaneously in order to improve body stability. Consequently, the lower limb is deliberately immobilized and weight-shift is minimized. On the other hand, the throwing motion of elite athletes may fully autonomous that self-implication on body stabilization is no longer needed, therefore the significant change of ground reaction force is observed during acceleration phase of dart throwing.

CONCLUSION: Athletes at different levels have shown distinctive stabilization strategies on lower limb during acceleration phase of dart throwing. The major difference is in the vertical force on athletes' front foot that with any slight shift on weight could affect the accuracy of dart throwing. As a step forward, it is to be expected that through and analyzing not only on acceleration phase but also on other phases of dart throwing, the throwing strategy will be even better understood that it can be a valuable resource for practicing and coaching in the sport of darts.

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