THE BIOMECHANICAL ANALYSIS OF LOAD CHARACTERISTICS DURING DISCUS THROWS WITH VARIOUS WEIGHT IMPLEMENTS

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The aim of this study was to clarify the load characteristics during throw with various weight discuses. Fourteen male discus throwers were analysed by using three-dimensional motion analyses. The maximum forces throughout the throw of the lighter discus (1.5 kg and 1.75 kg) were significantly lower than that of the competition weight discus (2.0 kg). However, the maximum force throughout the throw of the heavier discus (2.25 kg) was not significantly higher than that of the competition weight discus (2.0 kg). Focusing on the turn phases, the value of the forces were lower in the throw of the lighter discus. On the other hand, the maximum force in the throw of the heavier discus (2.25 kg) was greater than that of the competition weight discus (2.0 kg), except before release. This indicates that throw with various weight discuses changed load property.

KEY WORDS: three-dimensional analysis, heavier/lighter discus, training method

INTRODUCTION: Discus throw is a track and field event. Competitors throw a discus (2.0 kg) with a rotational motion within a circle that is 2.50 m in diameter. Throws with various weight implements have been used during training sessions (Bondarchuk et al., 1977). Escamilla et al. (2000) indicate that use of overweight and underweight training is carrying out for enhances speed-strength (power) development. In the hammer throw, Bartonietz (1994) reported that the maximum cable force increases in the throw with the use of heavier hammers. It is confirmed that when considering the force acting on the javelin, maximum force increases in the throw with a heavier javelin (Bartonietz, 2000). Takamatsu & Sakurai (2013) analysed throw with various discus weights (hereafter, various weight discuses) under the condition of the standing throw (without using a turn motion). The force acting on the discus tended to increase with increased amount of the discus weight. However, an analysis of throwing discuses with a turn motion has not been performed. Hence, to gain a further understanding of load properties throughout the throw with various weight discuses, a more detailed analysis of the kinematics of the throw is needed. Therefore, the aim of this study was to clarify the differences in the force between throws with various weight discuses.

METHODS: The participants were 14 male discus throwers (age, 21.0 ± 2.8 years; height, 1.77 ± 0.05 m; body mass, 93.8 ± 13.3 kg; personal best, 43.68 ± 6.24 m). In this study, the participants threw the various weight discuses (2.0 kg: competition weight, 1.5 kg: youth standard weight, 1.75 kg: junior standard weight, and 2.25 kg: heavier weight). Participants threw all discuses with maximum effort in a randomized order. Utilizing three high-speed video cameras (300 Hz), the three-dimensional coordinates of the centre of the discuses were obtained by means of the direct linear transformation method. The force applied on the discus by the thrower was determined from the following formula:

$$F = m\left(\frac{d^2s}{dt^2} - g\right).$$

In this formula, m is the mass of the discus, s is the three-dimensional position of the discus at any time t, g is the gravity vector (approximately –9.80 m/s^2 in the vertical direction). The coordinate data were smoothed with a Butterworth low-pass digital filter. Cut-off frequencies

ranging from 7.0 to 9.0 Hz were determined by the residual analysis proposed by Winter (2004). Turn motion was divided into 4 phases (SSP1, FP, SSP2, and DVP). Partition of normalized data was calculated based on the ratio of turn time in each phase (SSP1: 43%, FP: 10%, SSP2: 24%, DVP: 23%). To compare the maximum value of applied force during each phase of throw with the various weight discuses, ANOVA was performed, followed by Dunnett's multiple comparison with the 2.0 kg condition set as the control. The significance level was set at $p<0.05$.

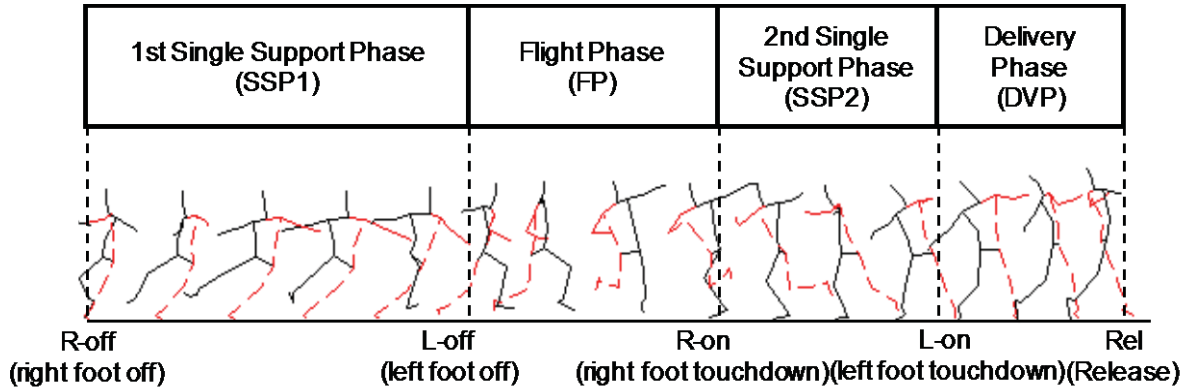

Figure 1: Definition of motion phases.

RESULTS: Table 1 shows the comparison of the maximum force throughout the throw with the various weight discuses. During SSP1 and FP, the force value of the 1.5 kg and the 1.75 kg discuses were significantly lower than that of the 2.0 kg discus. During FP, the force value of the 2.25 kg discus was greater than that of the 2.0 kg discus ($p=0.091$). During SSP2, the force value of the 1.5 kg discus was significantly lower than that of the 2.0 kg discus, and the force value of the 2.25 kg discus was significantly greater than that of the 2.0 kg discus. The maximum force throughout the throw is shown during DVP regardless of the weight of the discus. The force value of the 1.5 kg and the 1.75 kg discuses were significantly lower than that of the 2.0 kg discus.

Table 1
Comparison of the maximum force during turn phases in the throw with the various weight discuses

	Force [N]				
Phase	1.5kg	1.75kg	2.0kg	2.25kg	Multiple comparison
SSP1	124.0 ± 23.0	147.3 ± 37.3	165.7 ± 40.1	174.9 ± 36.9	1.5□1.75<2.0
FP	119.5 ± 41.4	133.4 ± 39.9	148.7 ± 36.1	161.4 ± 46.5	1.5□1.75<2.0
SSP2	186.3 ± 43.6	211.3 ± 51.6	223.5 ± 61.3	256.0 ± 60.5	1.5<2.0, 2.0<2.25
DVP	462.3 ± 41.3	492.1 ± 38.5	515.9 ± 45.9	517.8 ± 46.6	1.5□1.75<2.0

<: $p<0.05$

Figure 2 shows the average patterns of the applied force and the discus velocity in the throw, with the various weight discuses. The solid lines show the average force in the throw with the various weight discuses. As the weight of the discus was increased, the average force became higher. However, peak force value during DVP was not the highest in the throw with the 2.25 kg discus. The dotted lines show the average discus velocity in the throw with the various weight discuses. Discus velocity remained similar until the end of SSP2 (0-77%) and during DVP (77-100%), the discus velocity increased exponentially in all weight discuses.

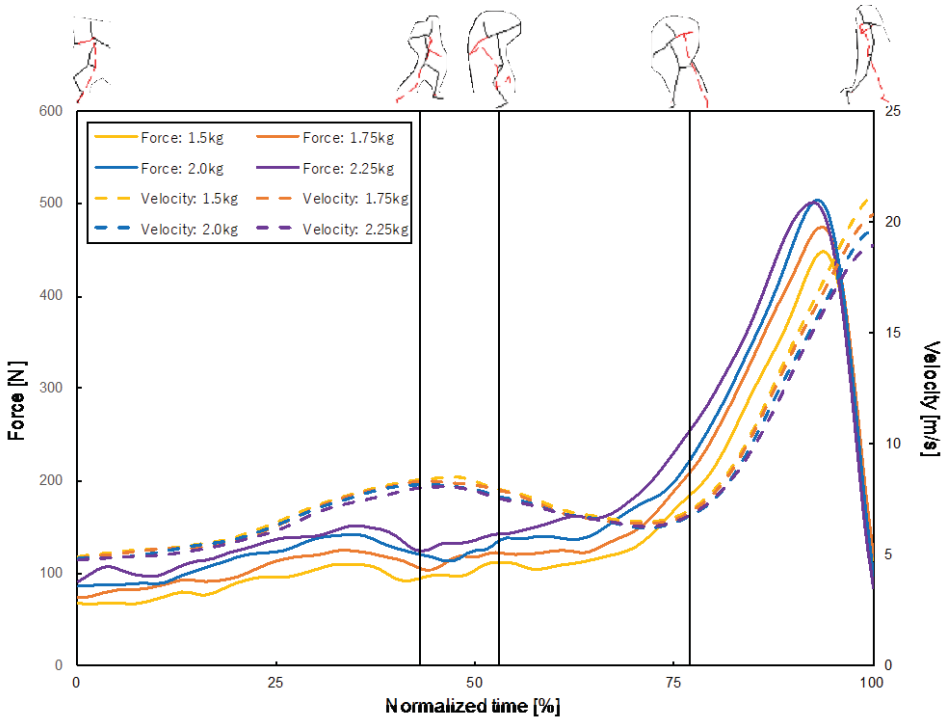

Figure 2: Average patterns of the force and the discus velocity in the throw, with the various weight discuses from R-off through to release.

DISCUSSION: The aim of this study was to clarify load characteristics during throws with various weight discuses. According to the parameters of the present study, the increase in maximum force was confirmed up to the throw with a 2.0 kg discus (Table 1). Bartonietz (1994) measured maximum cable force throw with the lighter weight hammers (5.0 kg and 6.26 kg, competition weight: 7.26 kg). This report indicated that throw with lighter hammers causes a load decrease. The present study similarly showed that throws with the lighter discuses (1.5 kg and 1.75 kg) cause a load decrease.

Speed-resisted training (e.g. uphill running and swinging a heavy bat) is a method for increasing external load and a means of training for specific strengths (Zatsiorski & Kraemer, 2006). It has been confirmed that the maximum force increases in the throw with the heavier implements (e.g. javelin and hammer) (Bartonietz, 1994, 2000; Hirose et al., 2015). In the present study, the maximum force in the throw of the heavier discus (2.25 kg) during SSP2 and FP were greater than that of the 2.0 kg discus. However, the maximum force throughout the throw of the heavier discus was not significantly higher than that of the competition weight discus (2.0 kg).

Figure 2 shows averaged patterns of the force and the discus velocity in throws with the various weight discuses from R-off through to release. Throws with the 2.25 kg discus demonstrated a higher force than the throws using other weight discuses from the beginning of the turn to the middle stage of DVP (0-92%). Hay & Yu (1995) suggested that a greater the increase in the velocity of the discus occurs during DVP. The present study also showed that the sharp increase in discus velocity was observed in DVP in all weights. Regarding discus velocity, the velocity at 77% motion phase was mostly the same in all scenarios, although differences were observed at release (100%). Therefore, when a throw occurred with the heavier discus, it was not possible to accelerate enough, compared to the other weight discuses. However, the reason why the throw with a 2.25 kg discus did not show the highest peak value of force was not clear. We estimate that the weight of the discus was too heavy for throwers and premature loss of contact could have occurred. In future research, we need to consider including the thrower's body movement.

CONCLUSION: The aim of this study was to clarify load characteristics during throws with various weight discuses. The maximum forces throughout the throw of the lighter discuses (1.5 kg and 1.75 kg) were significantly lower than that of the competition weight discus (2.0 kg). The maximum force in the throw of the heavier discus (2.25 kg) was greater than that of the competition weight discus (2.0 kg) except before release. This indicates that throws with various weight discus changed load properties.

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