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TOPICS: Biomechanics of discus thrower

Abstract: Seven high-level discus throwers (best performance 57 ± 3 m) participated to the present study. During the same session, they performed 12 throws (6 with a 1.7 kg discus and 6 with a 2 kg discus) in a random order. The throwing distance was computed from the velocity vector (magnitude, direction, height) at ejection. Kinematical data were collected by means of 3 video-cameras and a 3-D modelling of the throwing movement was processed according to the DLT method. Surface electromyograms (sEMG) of 6 arm-and-shoulder muscles of the throwing arm [Biceps brachii ; Pectoralis major ; Deltoideus pars superior ; Trapezius pars medialis ; Deltoideus pars medialis ; Latissimus dorsi] were recorded by means of a portable device. Thereafter, sEMG was integrated (iEMG) and related to the iEMG recorded during a maximal effort against an external resistance. Computed distance with a light discus was significantly longer and was the result of a faster discus speed at ejection. This was probably the result of an enhanced increase in discus velocity during the last throwing phase (Δt2da). There was no significant difference in the duration of the four preceding phases with 1.7kg compared to 2 kg discus. The total duration of the throwing movement was not significantly different between 1.7 and 2 kg discus. The EMG patterns of the different muscles were similar with both discuses when the beginning and the end of the muscle activity were considered. There was no significant difference between discuses when iEMG was summated on the whole throwing movement and related to the iEMG previously recorded during a maximal effort. These results suggest that the lighter discus might be used for high level training without kinematical alteration of throwing.

Key words: Discus throwing, Kinematics, modelling, electromyography, throwing technique.

1- Introduction

Discus throwing is a sport activity characterized by a complex technique (rotation and translation motion) which allowed to obtain the higher speed imparted to the discus at the release (Bartlett 1990). Athletes successful in this sport are able to rotate very fast in the throwing area (Bartlett 1990). To learn this complex technique, lots of coaches recommended doing the turn forward with an under mass discus. Nevertheless no data exists to know if the technique employed with an under mass discus (1.7 kg) is the same than with a competition discus (2 kg). Furthermore, in the discus literature, throwing technique is discussed mainly in relation with cinematographic data (Lindsay 1991, Stepanek and Susanka 1986). Simultaneously videographic and sEMG techniques can provide information about the pattern activity and the level activation of the involved muscles during throwing. Detailed analysis of the discus throw is facilitated by subdividing the movement into phases, separated by "key moments" mostly related to foot contact. The generally agreed subdivision produces five phases of the throw, which are preceded by the preliminary swings and followed by recovery. These phases, which have various names in the literature, are for a right-handed thrower (Bartlett 1990b):

- *Preparation*, a double support phase starting from the change in discus direction at the end of its backward swing and ending when the right foot breaks contact ($\Delta\ t_{1da}$).
- *Entry,* a single support phase which finishes with the left foot breaking contact ($\Delta\ t_{1sa}$).
- *Airborne,* which finishes with the right foot re-contacting ($\Delta\ t_s$).
- *Transition,* a single support phase which ends as the left foot lands ($\Delta\ t_{2sa}$).
- *Delivery,* which starts as a double support phase and which ends at release of discus ($\Delta\ t_{2da}$).

According to Barlett (1992), the doctoral thesis by Finanger (1964) is probably the only attempt to study electromyograhic activity during a real discus throw. Some electromyographic results of Finanger's study reported in Barlett review are difficult to explain:

- *deltoidus pars medialis* was only active during recovery, i.e. after discus release;
- *latissimus dorsi* was silent after a short burst of activity at the very beginning of the throw (during preparation phase and the beginning of entry) in contrast with the fact that hip lead over the shoulder and the arm is maintained back of the trunk.

However, as reported by Bartlett, there were many technical and methodological problems which limited the validity of some results in the pioneering study by Finanger.

We present the electromyographic data of six shoulder muscles, collected on high level throwers during a discus throw training session. In connection with surface electromyography (sEMG) of the shoulder muscles, we synchroneously collected 3D videographic data of the discus and the thrower's arm to relate muscle activity to the different phases of the discus throw.

The purpose of this study was to examine how mass of the discus influenced the kinematic characteristics and the activity of agonist muscles during throws using 3D videographic and surface electromyography (sEMG) techniques.

2- Methods and Procedures

Seven high-level discus throwers (23 ± 3 years, 108 ± 19 kg, 190 ± 6 cm, best performance : 57 ± 3 m) participated to the present study. During the same session in an indoor training hall, they performed 12 throws (6 with a 1.7 kg discus and 6 with a 2 kg discus) in a random order in the direction of a security web located 15 m in front of the throwing area. The throwing distance was computed from the velocity vector (magnitude, direction, height) at ejection (other factors were not taken into account). Kinematical data were collected by means of 3 video-cameras and a 3-D modelling of the throwing movement was processed according to the DLT method. Surface electromyograms (sEMG) of 6 arm-and-shoulder muscles of the throwing arm and shoulder [*Biceps Brach*ii (BB), *Deltoideus pars anterior*, (DA) and *pars medialis*,(DM) *Pectoralis Major* (PM), *Latissimus Dorsi* (LD), *Trapezius pars superior* (TS)]were collected and recorded by means of a portable device. Thereafter, sEMG was rectified and digitally integrated (iEMG) and, finally, related to the iEMG recorded during a maximal effort against an external resistance, performed before throwing.
A synchronisation signal was sent by a radio emitter to the EMG recorder and by small light emitting diodes (LED) to the three camcorders. The lights of these small LED were emitted a few millimetres in front of the lenses of the camcorders. The delay between LED signals and the EMG recorder signal was equal to 4 ms and taken into account in the synchronization process of the kinematic and EMG data.

2.1- Kinematic data processing

Coordinate transformation was performed so that the y-axis was horizontal and pointing towards the front and the x-axis was horizontal and pointing to the right of the throwing circle. The z-axis was pointing vertically upward. The z-y plane was parallel to a vertical plane that bisected the throwing sector. The horizontal velocity is the component of the resultants velocity in the x-y plane. The angle of release was determined from the horizontal and vertical velocities of release. Using the speed (v) and height (h) of release, the optimum angle of release (α) was computed using the following equation [1,2,3] (Lichtenberg and Wills, 1978):

$$\alpha = \sin^{-1} \left(\left(2+2gh/v^2 \right)^{-1/2} \right)$$

where g is the acceleration of gravity. The kinematical parameters were computed using the equation for uniformly accelerated motion:

The vertical component or the release velocity $$Vzf^2 = Vz_{te}^2 - 2gh \quad [1]$$

Flight time: $$t = (Vz_{te} - Vzf)/g \quad [2]$$

Flight range: $$dy = Vy_{te} \times t \quad [3]$$

The effect of air forces friction, lift and drag were not taken into account in this model because we were unable to measure the attack and attitude angles from the videographic data. Only the calculated throws higher than 80 % of the individual annual best performance were taken into account for further analysis.

2.2- EMG data processing

Muscle activation onset and offset were detected according to the 3 S.D. procedure. First, the mean value of rectified sEMG and its standard deviation were calculated with a 500 ms running average. The lowest values of the mean rectified sEMG during a 500ms sample were considered as the baseline EMG and its standard deviation as baseline S.D. The onset of a sEMG burst corresponded to the time when EMG was 3 S.D. above baseline S.D. for 25 ms. Offset was detected as the point when EMG was under this 3 S.D. limit.
For each throw, sEMG activity was integrated (iEMG) for the different phases and for the entire throw. iEMG values were thereafter divided by the duration of each phase and normalized to $iEMG_{MVC}$ measured during isometric contraction (see Protocols).

2.3- Protocols

First the throwers warmed up during 15 minutes in the throwing area, under the control of their coach.
Then, the skin was cleaned with an alcohol-ether-acetone solution in order to reach electrode impedance under 5 kΩ. Thereafter, sEMG data were collected during maximal effort against an external resistance in order to express muscle activation in percents of activation during a maximal effort ($iEMG_{MVC}$). A physical therapist exerted a manual opposition to the action of the different muscle groups during specific manoeuvres with the help of an assistant fixing the lower body as previously proposed by Knudson and Blackwell (2000) in their study on trunk muscle action in tennis. Each contraction lasted for about 5 s. Finally, the subjects went back on the throwing area, and performed five throws at 5 minute intervals.

3- Results

The kinetics of discus velocity (1.7 *vs* 2 kg) during the different phases of the throw is presented on figure 1. After a slow acceleration during the preparation phase, there was a plateau in discus velocity during entry and airborne phases. Velocity began to increase again at the end of transition phase before a steep acceleration during delivery at the end of transition and its release speed. The delivery phase has been reported as responsible for 62 % of the release speed of the discus.

Computed distance with a light discus was significantly longer (47.8 ± 1.0 *vs* 42.7 ± 2.9 m), which was the result of a faster discus speed at ejection (21.1 ± 1.1 *vs* 19.6 ± 0.5 $m.s^{-1}$**)** which was probably the result of an enhanced increase in discus velocity (12.9 ± 1.4 *vs* 11.0 ± 1.0 $m.s^{-1}$) during the last throwing phase (Δt_{2da}). There was no significant difference in the duration of the four preceding phases with 1.7 kg compared to 2 kg discus *(Fig 1).* The total duration of the throwing movement was not significantly different between 1.7 *vs* 2 kg discus (1.40 ± 0.3 *vs* 1.42 ± 0.2 s).

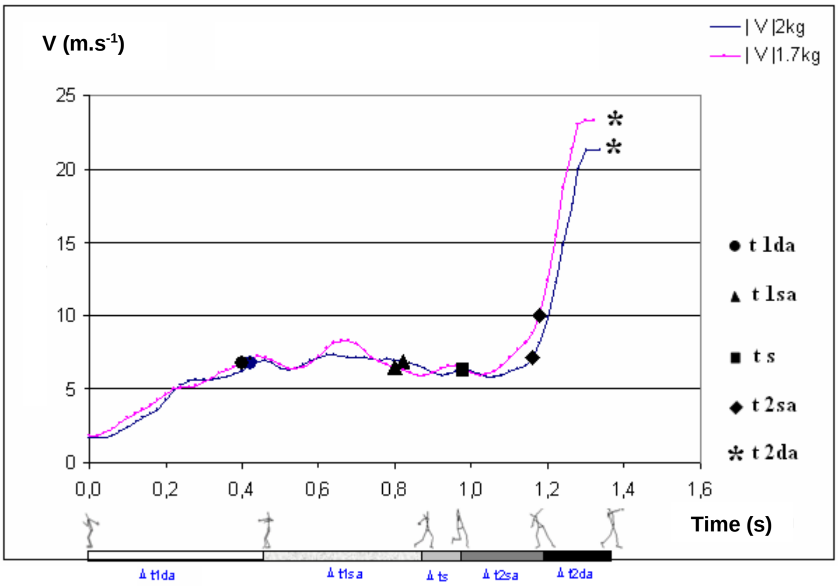

Figure 1: Comparison of variation of discus speed for two mass of the discus 1.7 *vs* 2 kg.

The typical EMG data of (DA), (DM) and (LD) during the different phases are presented on figure 2. The activity of (DA) was only observed during Δt_{2da}. In contrast, (LD) and (DM) were active during Δt_{1da} but were inactive during Δt_{2da}. This contrast between the activity of (DA) versus those of (DM) and (LD) were observed in all the subjects.

Figure 2 presents the beginning and the end of the EMG bursts of the different shoulder muscles.
(TS) was the only muscle which was active at the beginning and the end of the throw. The other muscles which were activated during the last phase (PM, BB, and DA) were inactive during the first phases. There was no EMG burst during Δt_{2da} for DM which was mainly active during Δt_{1da} and the first half of Δt_{1sa}.

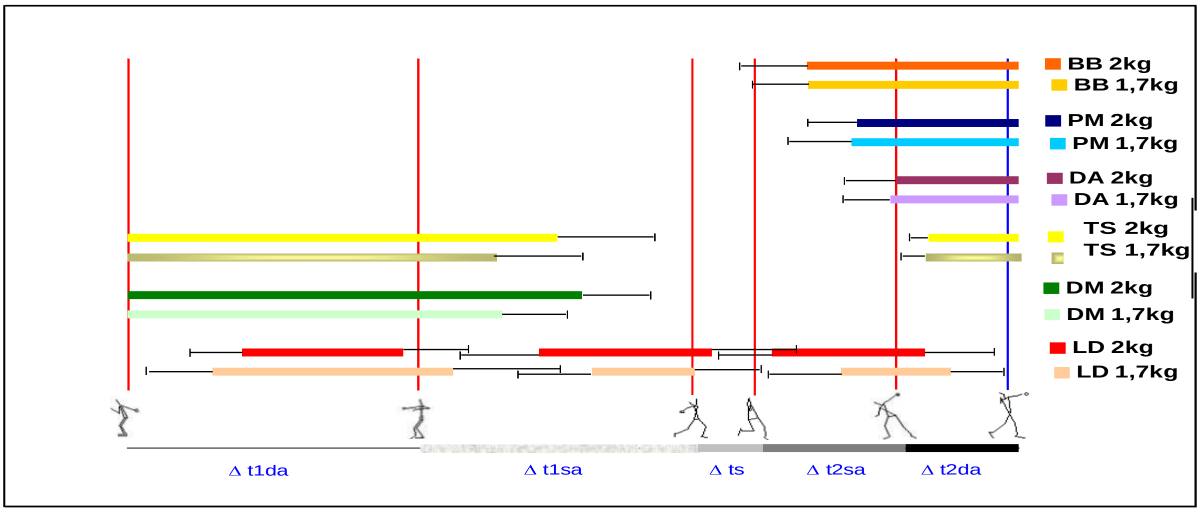

Figure 2: Comparison of iEMG for different muscles of the arm and shoulder with 1.7 *vs* 2 kg discuses. iEMG data correspond to the whole throwing movement and are expressed as percent of iEMG during a maximal effort.

The EMG patterns of the different muscles were similar with both discuses when the beginning and the end of the muscle activity were considered. There was no significant difference between discuses when iEMG was summated on the whole throwing movement and related to the iEMG previously recorded during a maximal effort *(Table 1).*

Muscles	**Normalized total iEMG (%) (2 kg)**	**Normalized total iEMG (%) (1.7 kg)**
Biceps brachii (BB)	26.24 ± 39.36	26,77 ± 11,12
Pectoralis major (PM)	22,36 ± 10,28	26,77 ± 11,12
Deltoïdus anterior (DA)	20,77 ± 10,88	23,71 ± 11,25
Trapezius superior (TS)	27,50 ± 10,34	27,70 ± 10,35
Deltoïdus medialis (DM)	29,39 ± 18,57	33,36 ± 29,23
Latissimus dorsi (LD)	41,87 ± 22,71	46,76 ± 13,60

Table 1: Comparison of normalized iEMG for 6 muscles of the arm and shoulder with 1.7 *vs* 2 kg discuses. iEMG data correspond to the whole throwing movement and are expressed as percent of iEMG during a maximal effort.

4- Discussion/Conclusion

In contrast with the Finanger's data cited by Bartlett, an EMG activity of (DA) were observed during the throw and (LD) was activated not only at the beginning of the preparation phase but also during entry, airborne and transition in our elite throwers. The peak level of LD iEMG corresponded to 47.9 of $iEMG_{MVC}$.
For Deltoideus anterior, higher iEMG was always observed during [Δt_{2da}] phase whereas for Deltoideus medialis iEMG was always observed during [Δt_{1sa}] phase. These results allow characterising muscle pattern activities in relation with throwing phases. (DA, PM and BB muscles). Moreover, during (Δt_{2da}) phase, the inter-thrower variability in the timing and the amount of EMG activity were more marked for some muscles. For example, one of the throwers showed a higher peak activity of the (DA) muscle. We hypothesize that the amount of iEMG activity is mainly related with the discus acceleration rather than the discus mass. These results allow characterising muscle pattern activities in relation with throwing phases.

The only significant difference between the 1.7 *vs* 2 kg discuses concerns the increase of velocity during the last phase (Δt_{2da}). All he other kinematical and electromyographical data were statistically identical when 1.7 *vs* 2 kg conditions were compared. Consequently, these results suggest that the lighter discus might be used for high level training without kinematic alteration of throwing. This should allow to decrease the risk of injuries in the beginners.

5- References

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