EFFECT OF THE TIMING OF THE POLE PLANT ON ENERGY LOSS IN THE POLE VAULT TAKE-OFF

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Some leading pole vault coaches recommend a late planting of the pole, at close to the instant of take-off. This technique is believed to reduce the energy lost during the take-off and produce a higher vault. The present study re-analysed data from a previous study in which male pole vaulters manipulated the timing of the pole plant. An individual analysis showed that the timing of the pole plant did not clearly affect the change in the total energy of the athlete/pole system during the take-off. This result suggests there might be no advantage in using a late pole plant. An individual analysis can sometimes be more likely to yield a true interpretation of experimental data than a group analysis.

KEY WORDS: energy, kinematics, kinetics, pole vault, take-off.

INTRODUCTION: The pole vault is a physically and technically demanding event that requires considerable ability in sprinting, jumping, and gymnastics. In biomechanical terms the aim of the athlete is to generate kinetic energy in the run-up and then use a long flexible pole to help convert as much of this energy as possible into the gravitational potential energy of the athlete at the peak of the vault. During the take-off phase the athlete plants the pole into the take-off box and executes an upwards running jump. The ground contact of the take-off stride lasts about 0.13 s, and in almost all jumps the instant of planting the pole occurs between the instants of touchdown and take-off (Gros & Kunkel, 1990). Planting the pole into the take-off box produces a sharp jarring of the athlete, and so some of the athlete's run-up kinetic energy is dissipated in their body (Linthorne, 2000; 2013). Some leading pole vault coaches recommend planting the pole at close to the instant of take-off as this technique is believed to reduce the energy lost during the take-off and hence produce a higher vault (Petrov, 1985). However, among highly successful pole vaulters there are considerable inter-individual differences the average timing of the pole plant, from near the instant of touchdown through to near the instant of take-off (Gros & Kunkel, 1990; Angulo-Kinzler et al., 1994).

Schade and Arampatzis (2012) examined the effect of the timing of the pole plant on the energy changes during the take-off. Their results did not support the view that a late pole plant is better. They tested six experienced male athletes where the athlete was asked to manipulate the timing of the pole plant ('normal', 'early', and 'late'). Video and force platform measurements were used to calculate the kinetic energy and gravitational potential energy of the athlete and the elastic strain energy in the pole. The total energy at the instant of touchdown was compared to the total energy at the instant of take-off. The authors presented plots which showed that as the timing of the pole plant moved closer to the instant of take-off, the energy stored in the pole and the energy lost by the athlete both decreased. Another plot showed that these two energy changes balanced each other out, and so the overall change in the energy of the athlete/pole system during the take-off was not affected by the timing of the pole plant. As supporting evidence Schade and Arampatzis reported there were no statistically significant differences in the change in the energy of the athlete/pole system between vaults with normal, early, and late plants.

A criticism of this study is that it analysed grouped data. An intervention study can produce considerable inter-individual differences due to differences in each participant's biological make-up and technique, and when investigating sports performance the coach is usually more concerned with the individual case than with the group outcome. Therefore, an individual analysis of the response of each participant to an intervention can sometimes be more fruitful than a group analysis (Bates, 1996). Therefore, the aim of the present study was to re-analyse the data reported by Schade and Arampatzis using an individual analysis.

METHODS: The study by Schade and Arampatzis (2012) examined energy changes during a pole vault take-off exercise. The exercise was a 'Jagodin', where the athlete performs the run-up, pole plant, and take-off as in a normal vault, but does not continue with the rock-back and bar clearance phases. Three decathletes and three specialist pole vaulters were tested. The study used high-speed video (250 Hz) to obtain kinematic data of the athlete, and force platforms were used to measure the ground reaction force of the take-off leg and the force exerted by the pole on the take-off box. The athletes had considerable inter-individual differences in their plant time, from 10 to 65% of the way through the ground contact time. The athletes then deliberately varied the timing of the pole plant through adjusting the distance of their take-off foot from the box by about ± 0.10 m. Each athlete performed 3–6 trials, and the athletes were able to adjust the timing of the pole plant by about 20% from their normal timing.

The three main energy variables that were calculated were: 1) the change in the elastic energy stored in the pole during the take-off, 2) the change in the mechanical energy of the athlete during the take-off, and 3) the change in the total energy of the athlete/pole system during the take-off. Energy values can be normalised to body weight and so may be interpreted as an equivalent change in the height of the athlete's centre of mass.

In the present study, plots were created of each energy variable against the time of the pole plant (with time zero set to the touchdown of the take-off foot). A straight line was fitted to the data for each athlete, and the gradient and its 90% confidence interval was calculated. The gradient was interpreted as 'decrease', 'constant', or 'increase' according to the smallest meaningful change in the gradient (Batterham & Hopkins, 2006). If the confidence interval spanned all three categories the result was deemed to be 'unclear'. In this study the smallest meaningful change in gradient was taken as 2.0 m/s. This is equivalent to an energy change of 0.1 m for a change in plant time of 0.05 s, and corresponds to a magnitude of improvement that I believe would justify the considerable time required to permanently change the athlete's take-off technique to take advantage of a more optimal timing of the pole plant.

RESULTS: The athletes that performed only three trials (Athletes A, B, and F) did not produce reliable results; the gradients were mostly unclear due to the large confidence intervals. The athletes that performed 5–6 trials (Athletes C, D, and E) produced more reliable results. For these athletes there was no clear effect of the timing of the pole plant on the change in the elastic energy stored in the pole during the take-off, or on the energy lost by the athlete during the take-off (Figures 1a and 1b). Likewise, there was no clear effect of the timing of the pole plant on the overall change in the energy of the athlete/pole system during the take-off (Figure 1c; Table 1). These results suggest there is no advantage in using a late pole plant.

DISCUSSION: The results from the individual analysis in the present study were only partially consistent with those of the group analysis performed by Schade and Arampatzis (2012). When the data in Figure 1a were considered as a group, they suggested that as the timing of the pole plant moved closer to the instant of take-off, the energy stored in the pole decreased. However, when the data from an individual athlete was considered, there was no clear effect of the timing of the pole plant on the energy stored in the pole. Likewise, when considered as a group the data in Figure 1b suggested that as the timing of the pole plant moved closer to the instant of take-off the energy lost by the athlete decreased, but when the data from an individual athlete was considered there was no clear effect. In contrast, the data in Figure 1c suggested that the energy of the athlete/pole system was not affected by the timing of the pole plant, both when considered as a group and when considered individually.

In a study that analyses multiple trials by several athletes, it is not appropriate to plot the data from all the athletes, fit a curve to the data, and then interpret the curve as indicating the strength of the effect of the manipulated variable. Data from many athletes can be very misleading about what happens to the individual athlete (Hay, 1985). There are often confounding variables (such as standing height, body mass, strength, technique, skill level,

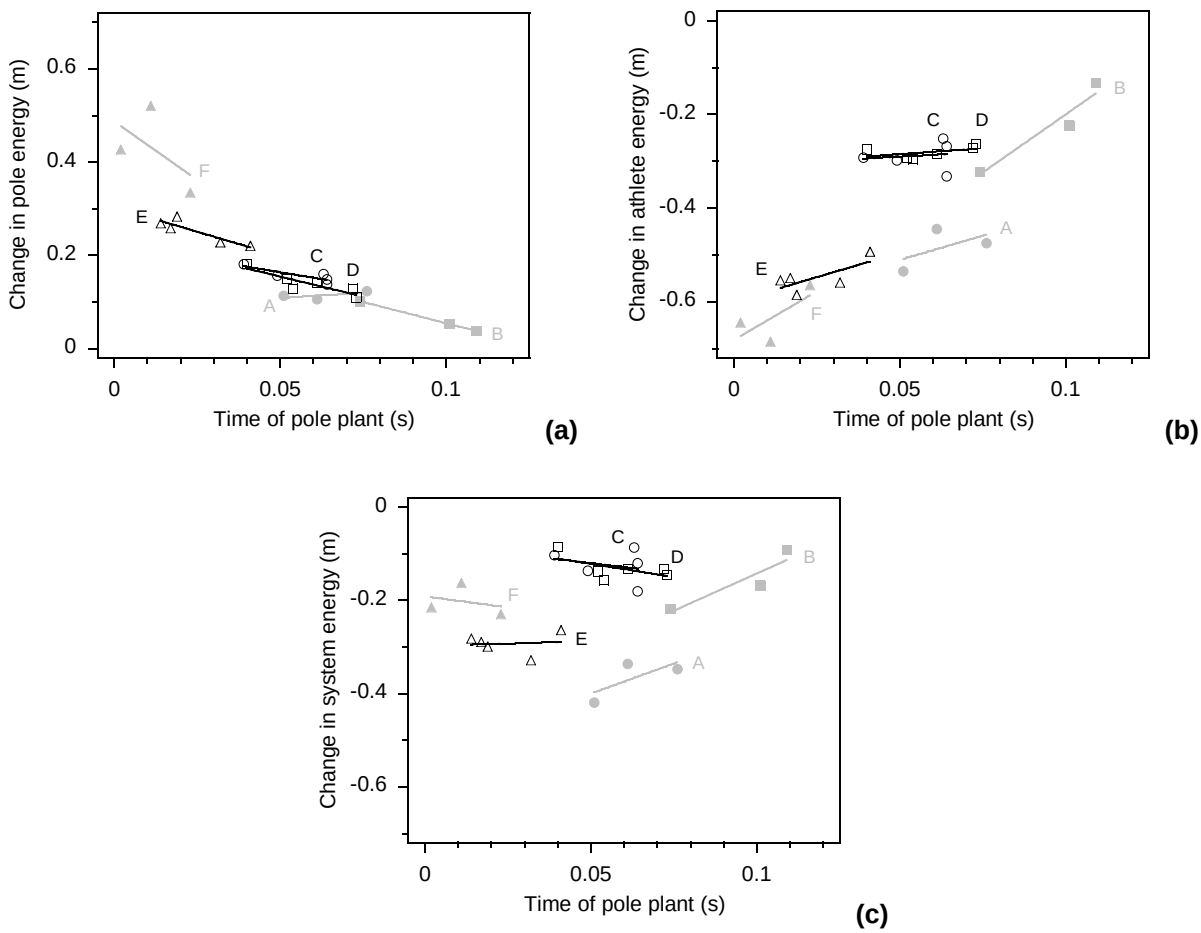

Figure 1: These plots show that the timing of the pole plant did not clearly affect (a) the change in the elastic energy stored in the pole during the take-off, (b) the change in the mechanical energy of the athlete during the take-off, or (c) the change in the total energy of the athlete/pole system during the take-off. Data for six experienced male athletes (A–F). The solid lines are a linear regression fit for the athlete; confidence bands have been omitted for clarity. Unreliable results are in grey. Time zero was the instant of touchdown of the take-off foot.

Table 1: Gradient of a linear fit to the data in Figure 1c (the change in the total energy of the athlete/pole system vs the time of the pole plant). Unreliable results are in grey.

Athlete	Event speciality	PB (m)	No. of trials	Gradient (m/s) (90% CI)	Interpretation
A	decathlon	4.35	3	2.6 (8.8)	unclear
B	decathlon	4.60	3	3.2 (6.1)	unclear
C	decathlon	4.90	5	–0.8 (3.9)	unclear
D	pole vault	5.35	6	–1.1 (1.6)	likely constant
E	pole vault	5.80	5	0.2 (2.6)	likely constant
F	pole vault	6.00	3	–1.0 (10.5)	unclear

etc.) that affect the response of an individual to a change in a manipulated variable. To determine the strength of the effect of a manipulated variable for the individual athlete, you would have to perform an experimental study on that athlete. Therefore, in a study of the effect of the timing of the pole plant on energy changes in the take-off, the result from an individual analysis are more likely to be a true interpretation of the data than the results from a group analysis.

The measurements of energy performed by Schade and Arampatzis (2012) were technically complex and logistically difficult. Unfortunately, in studies of elite athletes it is not always

easy to obtain a sufficiently large number of trials from the individual. It is also sometimes difficult to obtain data over a large range in the manipulated variable. The study by Schade and Arampatzis had only 3–6 trials by each athlete, and the timing of the pole plant was varied by only 0.021–0.035 s (i.e., about 16–27% of the total ground contact time). The present individual analysis therefore had clear results for only two of the six athletes. For a reliable individual analysis of the effect of pole plant time on energy loss in the take-off, you need at least 5 trials by the athlete and a change in plant time of at least 0.03 s. The present study might have had reliable outcomes for all six athletes if Schade and Arampatzis had recorded a few more trials by Athletes A, B, and F.

The study by Schade and Arampatzis (2012) looked at the acute effect of changes in the timing of the pole plant. An important feature of the study was that it used a single testing session in order to minimise intra-athlete variability. A more ecologically valid study would examine the effect of a sustained period of technique training that aimed to systematically change the timing of the athlete's pole plant. However, such a study would likely show greater variability in the jumps due to the longer time between measurements. The study might not produce a reliable result for the effect of the timing of the pole plant due to the confounding effects of changes in other variables.

The study by Schade and Arampatzis (2012) (and the present study) used the instant of take-off as a key instant at which to compare energies. The instant of take-off is an appropriate choice in the long jump and high jump because after take-off the athlete is no longer in contact with ground and so the athlete's energy remains constant. However, in the pole vault the athlete remains in contact with ground after take-off (via the pole), and so the total energy of the athlete/pole system continues to change after take-off. The benefit of a later pole plant might become evident if the key instant at which energies are compared is not the instant of take-off, but some later time.

CONCLUSION: An individual analysis can sometimes be more likely to yield a true interpretation of experimental data than a group analysis. An individual analysis of the data from Schade and Arampatzis (2012) showed that the timing of the pole plant did not clearly affect the change in the total energy of the athlete/pole system during the take-off. This result suggests there might be no advantage in using a late pole plant.

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