# Run-up velocities of female and male pole vaulting and some technical aspects of women's pole vault

NSA © by IAAF
12:1; 63-76, 1997

by Horst Adamczewski and Bettina Perlt

*"The authors describe their experiences with the laser distance measurement (LAVEG) of the approach velocity during competition and training and arrive at the following conclusions: In all age categories of the men's and women's pole vault the run-up velocity is an important factor affecting performance. In the women's pole vault there is an even greater potential for improvement than in the men's pole vault and in the other athletic events. As far as the run-up velocity is concerned, the German women pole-vaulters have managed to keep up with the best in the world. Regarding the pole vault technique as a whole, the best women in the world have got closer to the men's technical model. The take-off is mastered in the form of a "free take-off" or at least without a backward lean of the trunk. The hang phase is very marked, the long swing of the leg is performed with an extended leg, and the hips are brought up to or beyond shoulder height during the rock-back. In spite of equally significant technical progress there is still potential for improvement, especially in the vertical work on the pole and the bar clearance. This means that the special strength of the trunk and arms is becoming a crucial factor in determining performance. Grip heights of 4.35 to 4.45m and a vaulting-height/grip-height differential of between 0.65 and 0.75m – and thus vaulting heights of between 4.80 and 5.00m – are realistic targets for the next ten years."*

*Dr Horst Adamczewski and Dr Bettina Perlt are research collaborators at the Institute of Applied Training Science (IAT) Leipzig, Germany.*

*(Translated from the original German by Jürgen Schiffer.)*

## 1 Problem

The connection between run-up velocity and jumping or vaulting performance has always been the focus of interest in the theory and practice of the athletic jumping events. In the 1960s, the introduction of electro-optical methods (light barriers) for measuring the approach time in training and competition opened up new possibilities for exploring this connection. Since these methods can give immediate information about the run-up velocity, they have become routine procedures used in the long and triple jump as well as in the pole vault. In 1966/67 the first measurements were conducted in the men's pole vault. The velocity in two 5m sections – 15-10m and 10-5m before the box – was measured (Adamczewski/Dickwach 1991, 15n.). This measurement method has also become popular internationally (Fraley/Fraley 1997, 16) and was even used at World Championships (Gros/Kunkel 1988) and Olympic Games (Gros/Kunkel 1990, 229n.).

Since 1975, measurements of the run-up velocity in the men's pole vault have been conducted relatively regularly and have been evaluated every three to five years (Adamczewski/Dickwach 1991, 17n.). These measurements showed that in elite pole-vaulters there is a correlation between the competition performance and the run-up velocity, and by now this correlation has become the standard for the evaluation of the individual run-up velocities. The regression lines, which served as a guide and standard, ran almost parallel, with only one exception of a rise of 0.5, although they increased steadily. This means that in this time, with an increase in run-up velocity of the same magnitude, roughly the same increase in vaulting height could be expected – i.e. a gain in height of about 0.5m in the case of an increase in velocity of 1m/sec. However, this also meant that after about 3-5 years the athletes had managed to vault significantly higher although their run-up velocity had remained the same. This was attributed not only to the particularly dynamic development of pole vaulting technique and equipment (pole material, artificial runways, landing mats, shoe material) but also to

the development of trunk and arm strength and special vaulting ability during this time.

Therefore, in the interest of the development of all performance-determining factors, the relationship between the run-up velocity and the height cleared in the pole vault should be checked at certain intervals. After the inclusion of the girls' and women's pole vault in the programme of the championships of the German Athletic Federation (DLV) in 1991 and 1992 respectively, which also meant that this new event became a subject of coaching research, many questions dealing with the connection between run-up velocity and vaulting height had to be reasked.

At that time, as in the women's pole vault now, there were not yet any age-group specific guides for the run-up velocity even in the male youth category. For this reason it was decided to develop sex and age-group specific guides for the run-up velocity in the pole vault as a way of making use of run-up time measurements in practical coaching.

After preliminary measurements and evaluations (Adamczewski/Kruber 1993, 17n.) the hypothesis that a change in the run-up velocity of 1m/sec in the men's pole vault leads to a change in the vaulting height of about 0.5m was extended to the women's pole vault and to the female and male youth categories.

## 2 Investigation methods

The run-up velocity was determined by carrying out approach time measurements by means of pairs of electronic light barriers (vertical distance between the photocells of the double light barrier: 0.40m) in the last two 5m sections of the run-up. Normally (i.e. if there were no disturbances by display boards etc.) the light barriers were placed at the following distances from the back wall (upper edge) of the box:

men: 16, 11 and 6m,
male youth athletes: 15.5, 10.5 and 5.5m,
female youth athletes and women: 15, 10 and 5m.

These differences proved to be useful and to some extent even necessary because of the different grip heights (pole lengths) and the different positions of the take-off point. Placing the light barriers closer to the box in the girls' pole vault – which would be favourable with regard to the position of the take-off point – would obstruct the judges' view in competition and is therefore impossible. The increase in distance in the men's pole vault, where the light barriers were placed 15m, 10m and 5m before the far side of the box from the 1960s to the 1980s, took into account the fact that take-off points are now more and more often clearly over 4m in front of the back wall of the box. Tarasov, for example, took off at 4.50m in front of the back wall of the box at the World Championships in

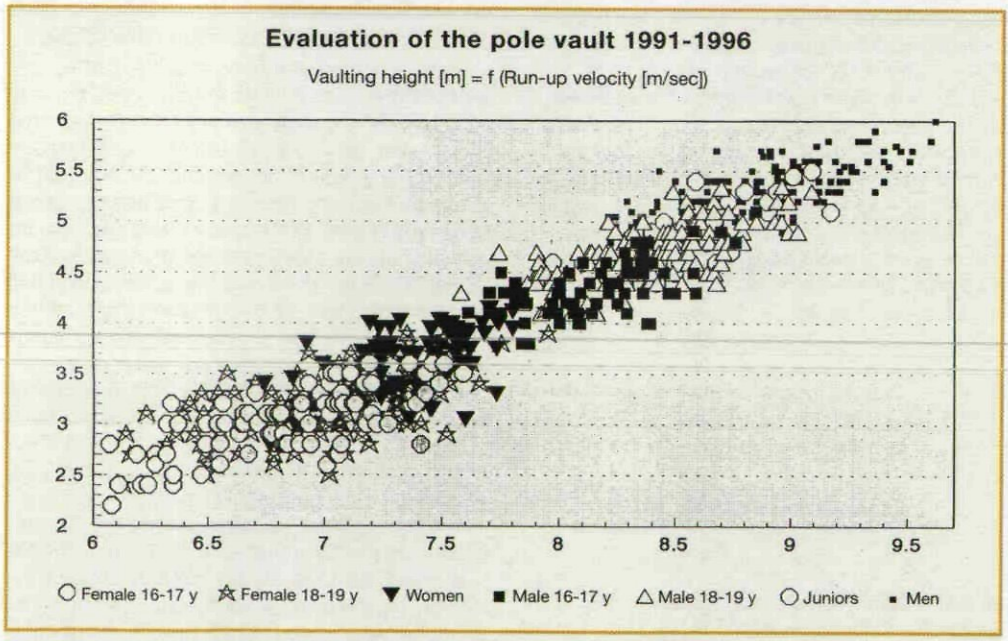


**Figure 1: Relation between the pole vault performance [m] and the run-up velocity [m/sec] in the women's and men's pole vault between 1991 and 1996 (n=725; 326 of who are women and 399 men)**

Stuttgart 1993. By measuring the run-up time by means of light barriers, the mean velocities in the last 5m sections of the approach are determined. Parallel to the measurement of the run-up time in several selected competitions, a laser distance measurement device, LAVEG, was used for the determination of the velocity course during the complete run-up. This measuring technique was described in detail by DICKWACH/HILDEBRAND/PERLT (cf. NSA no. 4/1994, p. 31).

All vaults were filmed simultaneously with a panned camera (placed at right angles to the runway in the area of the last step or the take-off). On the basis of these video shots, the length of the last two strides and the position of the take-off point were determined. Furthermore, phases of the technique of selected athletes during their best vaults were linked to picture sequences. From 1991 to 1996, 71 competitions – 30 in female and 41 in male pole vaulting – were included in the evaluation. 53 of these competitions (26 female/27 male) were German Championships (outdoor and indoor) of the youth categories 18-19 and 16-17 years and the seniors. The men's pole vault was also evaluated at the 1993 World Championships in Stuttgart.

## 3 The connection between run-up velocity and pole vault performance

### 3.1 Presentation of results

The following presentation and the subsequent discussion of the results is done bearing in mind that the run-up velocity during the pole vault is only one of several parameters affecting the vaulting height. In this context, vaulting technique, special vaulting ability and special trunk and arm strength should never be ignored either because they are also very significant. 71 competitions were evaluated, and the size of the subject sample was n = 725 (326 female/399 male athletes) (see *Figure 1*)

The number of vaults analysed is not higher because in order to keep the data as meaningful as possible only the maximum height cleared by the individual athletes and the corresponding run-up velocity in the last 5m section were included in the analysis. The compilation of the vaulting heights and the corresponding run-up velocities of all male and female vaulters from the youth category 16-17 up to the adult categories in one diagram (*Figure 1*) leads to an extended cloud of dots whose centre ($\bar{y}$ = mean value of the vaulting height: 4.175m / $\bar{x}$ = mean value of the approach velocities: 7.90m/sec) is the transition area between the female (senior category) and the male vaulters (male youth category 16-17).

In contrast to the first evaluations carried out in 1993 (ADAMCZEWSKI/KRUBER 1993, 16) there is no longer a gap between the women and the men in terms of vaulting height and run-up velocity. This means that in Germany the women have caught up with the male youth category 16-17 athletes in both criteria.

#### 3.1.1 Men (age groups: senior; junior; male youth 18-19; male youth 16-17 years

The vaulting heights and run-up velocities of the sample of male pole-vaulters which were measured between 1991 and 1996 and have been classified according to age groups are presented in *Figure 2*. With the exception of male youth 18-19 the samples of the individual age groups fulfil the demand that 68% of the vaulting heights should be in the band of $\bar{y} \pm s$ (mean value of the vaulting height ± standard deviation). This means that no greater deviations from the normal distribution can be considered. In each age group there is a highly significant correlation between the approach velocity and the vaulting height (totally linear correlation coefficients r from 0.64 to 0.75).

The regression lines y = by + a (y: vaulting height in metres; x: approach velocity in metres per second; *b*: rise of the line; *a*: absolute term), which characterise the trend of the connection between run-up velocity and vaulting performance of the samples in the individual age groups, run roughly parallel to one another with the exception of the line of the juniors. This means that the rise (*b*) of the lines is approximately equal. On the other hand, this means that the increase in vaulting height which is expected because of an similar increase in run-up velocity from male youth 16-17 to the men's category – shows no great difference, except possibly the juniors.

The increases of 0.527 in the men, 0.606 in the male age group of 18-19 years and 0.634 in the male age group of 16-17 years (cf. *Figure 2*) mean that because of the increase in run-up velocity of 1m/sec in these samples an average increase in vaulting height of 0.53m (men) and 0.63m (male age group of 16-17) was to be expected in the period of investigation. The significantly different height of the approximately parallel regression lines (differences regarding the absolute term *a* of the regression line) means that in the individual age groups the vaulting heights achieved were increasingly higher although there was no change in run-up velocity from the male age group of 16-17 to the men's category. For example, the average heights at a run-up velocity of 8.5m/sec were 4.55m in the male age group of 16-17, 4.76m in the male age group of 18-19 and 5.12m in the men's category.

These results correspond with many years' empirical evidence and can on the one hand be explained by the general age-affected performance ability and on the other hand by the differences between the age groups in terms of the development of technique as well as jumping, special trunk and arm strength.

For example, regarding the difference between vaulting height and net grip height (grip height minus 0.20cm box depth), which is very much influenced by technique as well as special trunk and arm strength, there are clear age-specific characteristics in the male categories which have been obvious for many years. In the male age group of 16-17 0.25m and more, in the male age group of 18-19 0.50m and more and in the men (international) 1.00m and more are regarded as good differentials between vaulting height and net grip height.

If one ignored these age-group-specific manifestations of certain characteristics and carried out a correlation and regression calculation of the relationship between run-up velocity and pole vault performance across the complete male sample ($y = 0.951x - 3.24$; $r = 0.85$) this inhomogeneity correlation would lead to a pseudo-correlation. In some cases this could mean that the influence of the run-up velocity on the vaulting height would be overestimated and thus evaluated wrongly (rise $b = 0.951$).

### 3.1.2 Women (age groups; women; juniors; female youth category 18-19 years; female youth category 16-17 years

The first women's pole vault competition where the run-up velocity was measured was an unofficial competition of athletes from all over Germany at the last athletics championships of the GDR in Dresden on August 8, 1990. Since the inclusion of the women's pole vault in the championship programme of the DLV in 1991, run-up time measurements have so far been conducted at all German youth and adult championships. The development of both the vaulting heights achieved at the championships and the corresponding run-up velocities (in each case as an average of three and ten) from the start of the measurements until 1996 is presented in *Figure 3*. In all three age categories the championship performances reflect a significant development in this still young event. Furthermore, it unexpectedly reveals that performance progress from 1991 until 1996 is closely connected with the improvement in run-up velocity.

The vaulting heights and run-up velocities of the whole sample of female athletes for the period from 1991 to 1996, and classified into the female age group 16-17, female age group 18-19 and women age groups, are presented in *Figure 4*. As far as the normal distribution is concerned, the female age group 16-17 and 18-19 samples fulfil the demand that 68% of the performance

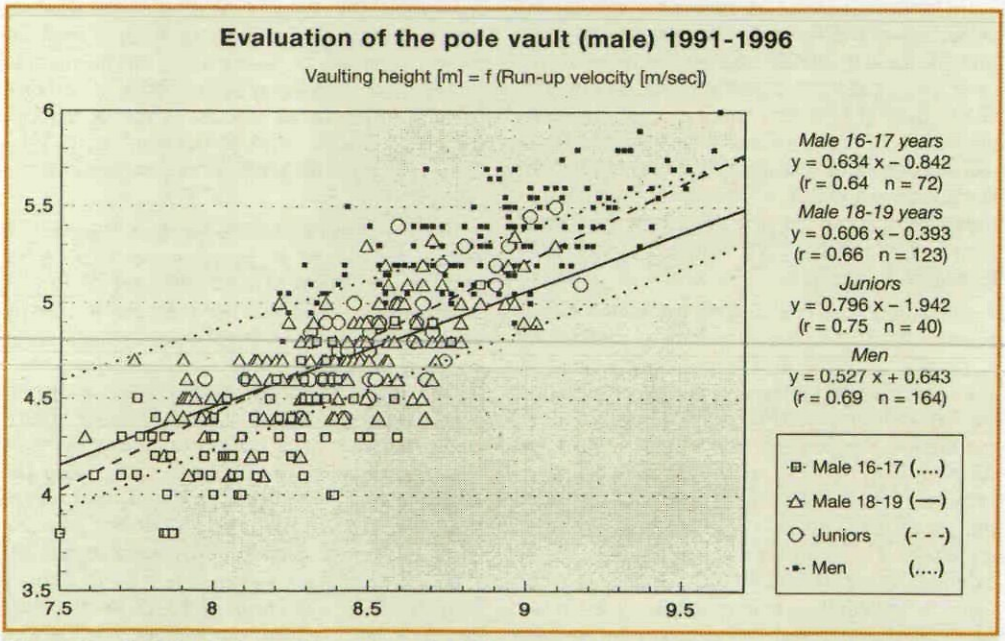


**Figure 2: Relation between the pole vault performance [m] and the run-up velocity [m/sec] in the male age categoria 16-17 years, 18-19 years, juniors and men during the period between 1991 and 1996**

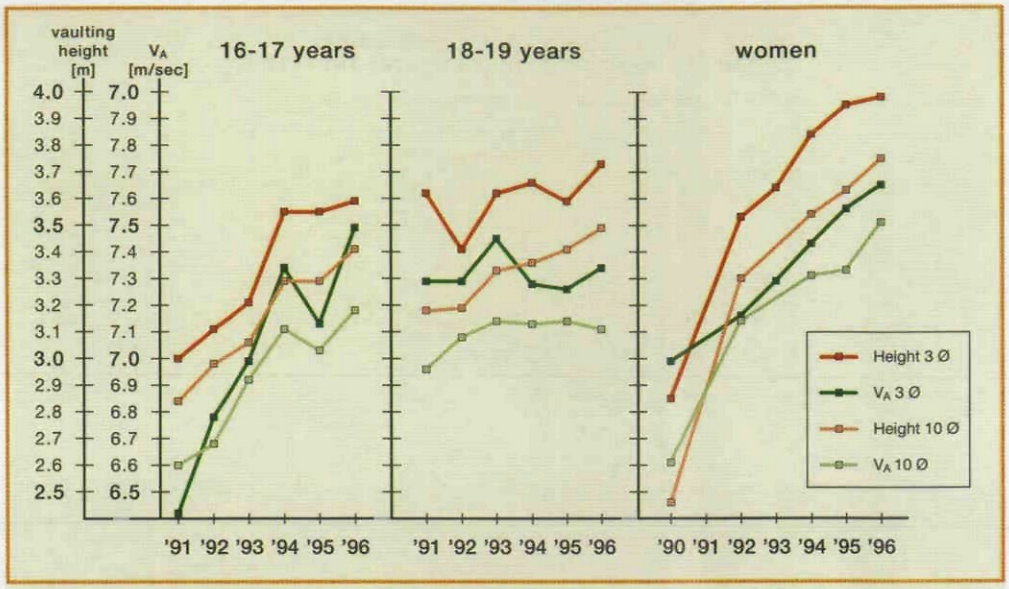


**Figure 3: Development of the average of first three and the average of first ten of the competition performance (vaulting height) and the run-up velocity (VA) at the German Championships in the female 16-17 years category (outdoor) and 18-19 years (indoor/outdoor) as well as of the women (indoor/outdoor) between 1991 and 1996**

values must be in the interval of the mean value of vaulting height plus/minus standard deviation ($\bar{y} \pm s$). In all three age groups the run-up velocity correlates with the vaulting height with totally linear correlation coefficients from r = 0.59 (female age group 18-19, women) to r = 0.70 (16-17 years). The regression lines have inclinations of b = 0.537 (18-19), b = 0.604 (16-17 years) to b = 0.684 (women). This means that in these samples, as for the men, from an increase

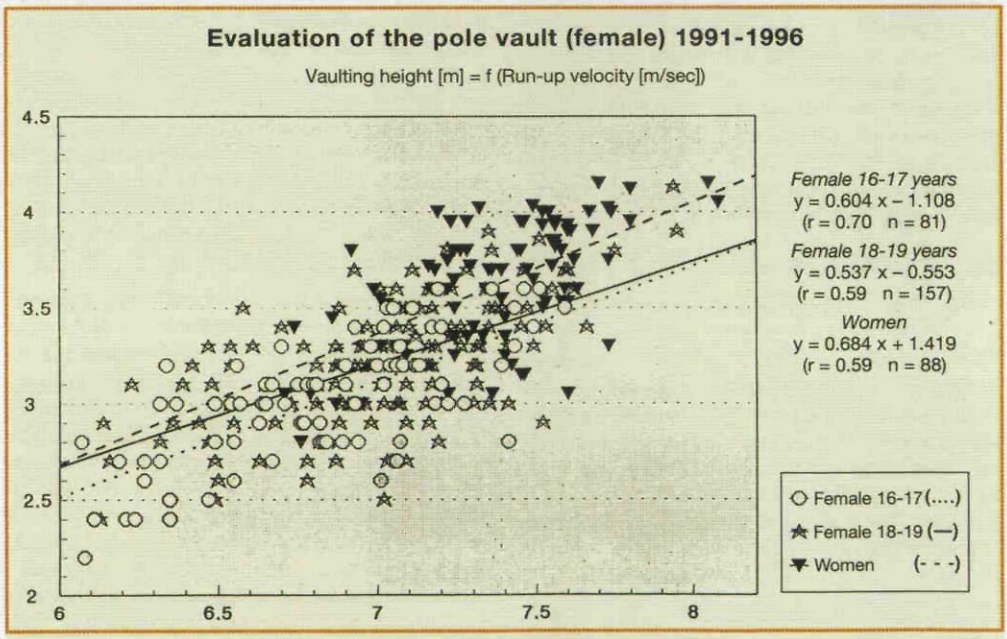


**Figure 4: Relation between the pole vault performance [m] and the run-up velocity [m/sec] in the female age categoria 16-17 years, 18-19 years and women during the period between 1991 and 1996**

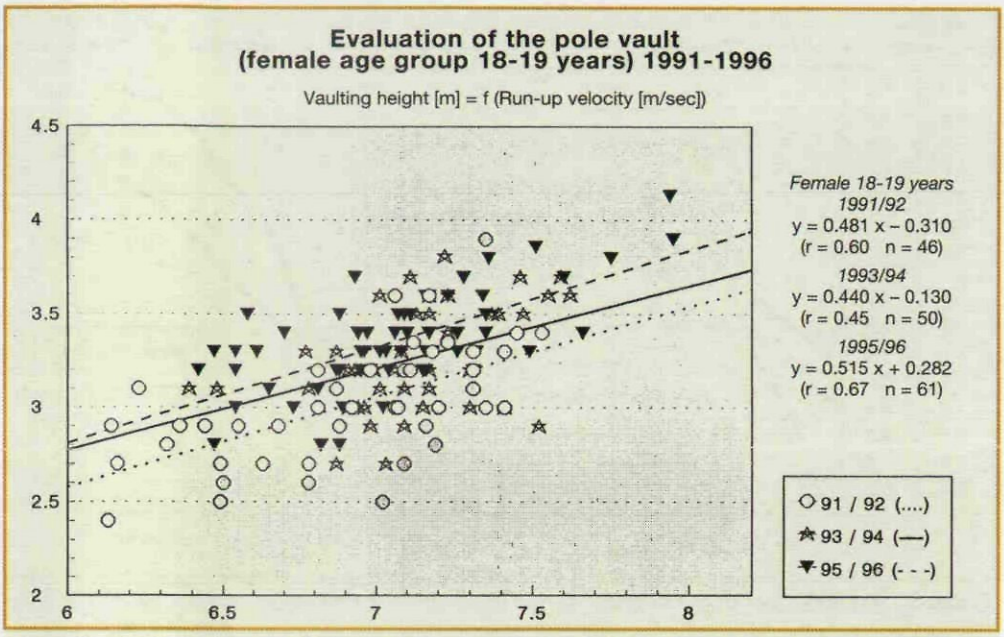


**Figure 5: Relation between the pole vault performance [m] and the run-up velocity [m/sec] in the female age category 16-17 years between 1991 and 1996 (as divided into two periods of two years each)**

in run-up velocity of 1m/sec an increase in heights cleared of 0.54m (female age group 18-19) to 0.68 (women) can be expected.

In *Figure 5* the run-up velocities and the vaulting heights of the female age group 18-19 sample are presented for periods of two years each. It can clearly be seen that during the period of the investigation the girls, unlike the male youth athletes, managed to vault 0.10 to 0.15m higher every two years with an identical run-up velocity. This result can be explained by the very rapid development of technique and conditioning in a young event like the women's pole vault.

### 3.2 Discussion of results

The fastest run-up velocity yet recorded in a valid vault* was achieved by S. Bubka in Seoul 1988 when he cleared 5.70m after an approach at 9.90m/sec (Gros/Kunkel 1990, 248). In the investigation period from 1991 to 1996 no faster run-up velocities were measured. S. Bubka achieved a run-up velocity of 9.62m/sec in his 6.00m vault at the 1993 World Championships in Stuttgart, and S. Huffman (USA) ran 9.60m/sec at the same competition when he cleared a height of 5.80m.

* At a competition in Berlin in 1985 whereas S. Bubka failed at the initial height three times, we measured 10.0m/sec (Adamczewski/Dickwach 1991, 18).

In the women's pole vault the situation is completely different. While in 1992 the highest run-up velocity we measured was 7.73m/sec (T. Cors in Munich on June 21, 1992, clearing a height of 3.30m) in 1996/97 the German athletes C. Adams in Munich on February 25, 1996, over a height of 4.05m with a run-up velocity of 8.08m/sec, N. Ryshich on June 21, 1996, over 4.15m – (world junior record – with a run-up velocity of 8.05m/sec, S. Schulte on February 23, 1997, over 4.10m with a run-up velocity of 8.06m/sec) as well as the US American S. Dragila (in Erfurt on February 5, 1997, with a run-up velocity of 8.06m/sec over 4.13m) reached run-up velocities over 8m/sec in the last 5m of the run-up.

Using video analysis Grabner (1996, 72) measured a maximum horizontal velocity of 8.2m/sec at the moment of the last touchdown for the world record vault of the Chinese C. Sun over 4.11m in Pulheim on February 3, 1995. According to previous experience of LAVEG measurements of the pole vault run-up velocity, this momentary value should not be valued higher than the 5m section velocities mentioned above. For example in the 4.13m vault of S. Dragila in Erfurt the LAVEG measurement produced a momentary maximum velocity value of 8.24m/sec, whereas the 5m light barrier measurement produced a result of only 8.06m/sec.

The continuous and rapid development of the run-up velocity in the area of the women's pole

vault has led to a reduction of the distance between the fastest women and men pole-vaulters to clearly below 2m/sec (a difference of 1.82m/sec between S. Bubka and C. Adams). However, in spite of this considerable progress the difference between the run-up velocities in the men and women is still much greater than in the long and high jump (see *Table 1*).

**Table 1: Percentage relation of known approach velocities of men and women in the pole vault, long and high jump (as of March 1997)**

| | Approach velocity [m/sec] | | |
|---|---|---|---|
| Event | Men | Women | % |
| Pole vault | 9.90 S. Bubka | 8.08 C. Adams | 81.6 |
| Long jump | 11.17 C. Lewis | 10.25 H. Drechsler | 91.8 |
| Triple jump | 10.75 M. Conley | 9.50 I. Kravets | 88.4 |

Although it is not clear to what extent the carriage of the pole is responsible for this great difference, it is assumed that this difference shows that the women pole-vaulters have greater scope for improving their maximum velocity than the women long and triple jumpers. The existence of greater run-up velocity potential in the women is also underlined by the fact that the highest yet run-up velocity of a female youth category 18-19 pole-vaulter (N. Ryshich) of 8.05m/sec is in the absolute peak area for the women.

As far as the significance of the run-up velocity for the pole-vaulting performance of a sample is concerned, the rise (b) of the regression line ($y = bx + a$) plays an essential role. This rise is an indication of the gain or loss in expected vaulting height. More specifically, this means that from a change of the run-up velocity of 1m/sec a change of the vaulting height (in metres) which corresponds to the value of the rise (b) can be expected. This means that in the case of a rise of 0.5m an increase in velocity of 1m/sec would lead to an expected increase in vaulting height of 0.5m.

The available results support the previously-mentioned hypothesis of a value of 0.5 which is relatively independent of time (and to a limited extent also of performance) for the rise of the regression line with regard to the connection between run-up velocity and vaulting height in the men's pole vault. The sample of 164 competition vaults of the men between 1991 and 1996 with a mean value of the vaulting height of 5.33m and of the run-up velocity of 8.9m/sec shows an increase of 0.527.

For the samples of the female and male athletes of the youth categories 18-19 and 17-18 years over the period from 1991 to 1996 there were regression lines with increases of between 0.537 and 0.634. The regression lines for the juniors ($b = 0.796$), which were considered separately from the male age group of 18-19 years, and of the women ($b = 0.684$) deviate somewhat. A temporally differentiated consideration of the female category 18-19 sample over three two-year intervals from 1991 to 1996 (*Figure 5*) led to rises of 0.440 up to 0.515. These results support the hypothesis that with a change of the run-up velocity of 1m/sec both in the female and the male area of the pole vault of all age categories an increase in vaulting height of about 0.5m can be expected.

Starting from this hypothesis and based on previous experience in research in the pole vault from the female and male categories 16-17 years to the adult category, the following guides for the gender and age-category-specific assessment of the connection between run-up velocity and pole vault performance have been developed (*Table 2*).

The orientation line of the next age group up serves as the upper standard for the preceding age group. For the women and the men an upper standard is given because there is no higher age group. The orientation line for the women and the male age group of 16-17 years is currently identical. In contrast to the rise b of the guideline a temporally limited validity is assumed for the absolute terms a, especially for women, because of the rapid development of technique and special physical ability in this young event.

## 4 The technique of the women's pole vault

At the 17th European Athletics Coaches Association Congress in Berlin from January 15 to 17, 1993, it was still true to say that "in the women's pole vault there has as yet been only a limited development in the individual national associations. However, a detailed evaluation of this

**Table 2: Guides to the gender and age-category-specific assessment of the connection between run-up velocity and pole vault performance (y – vaulting height [m]; x – run-up velocity [m/sec])**

| | | | |
|---|---|---|---|
| Men (upper standard) | $y = 0.5x + 1.25$<br>$y = 0.5x + 1.00$ | Women (upper standard) | $y = 0.5x + 0.50$<br>$y = 0.5x + 0.25$ |
| Junior | $y = 0.5x + 0.75$ | Female age group 18-19 / Juniors | $y = 0.5x \pm 0.00$ |
| Male age group 18-19 | $y = 0.5x + 0.50$ | | |
| Male age group 16-17 | $y = 0.5x + 0.25$ | Female age group 16-17 | $y = 0.5x - 0.25$ |

```
==========================================================================
        LAVEG -- Auswertung                          IAT eV Leipzig
==========================================================================
erf7sf05.dat              Erfurt 5.2.97 / Dragila, S. 4.13m / 2.+

   Angaben zur Anlaufgeschwindigkeit

      s [m]          v [m/s]
--------------------------------------------------------------------------
      5.06            7.95
     10.06            7.91
     15.07            7.60
     19.99            6.93
     24.99            6.10
     29.98            4.40
==========================================================================
absolutes Maximum der Geschwindigkeit :   8.24 m/s
          mit dem dazugehörigen Weg :     6.39 m
==========================================================================
```

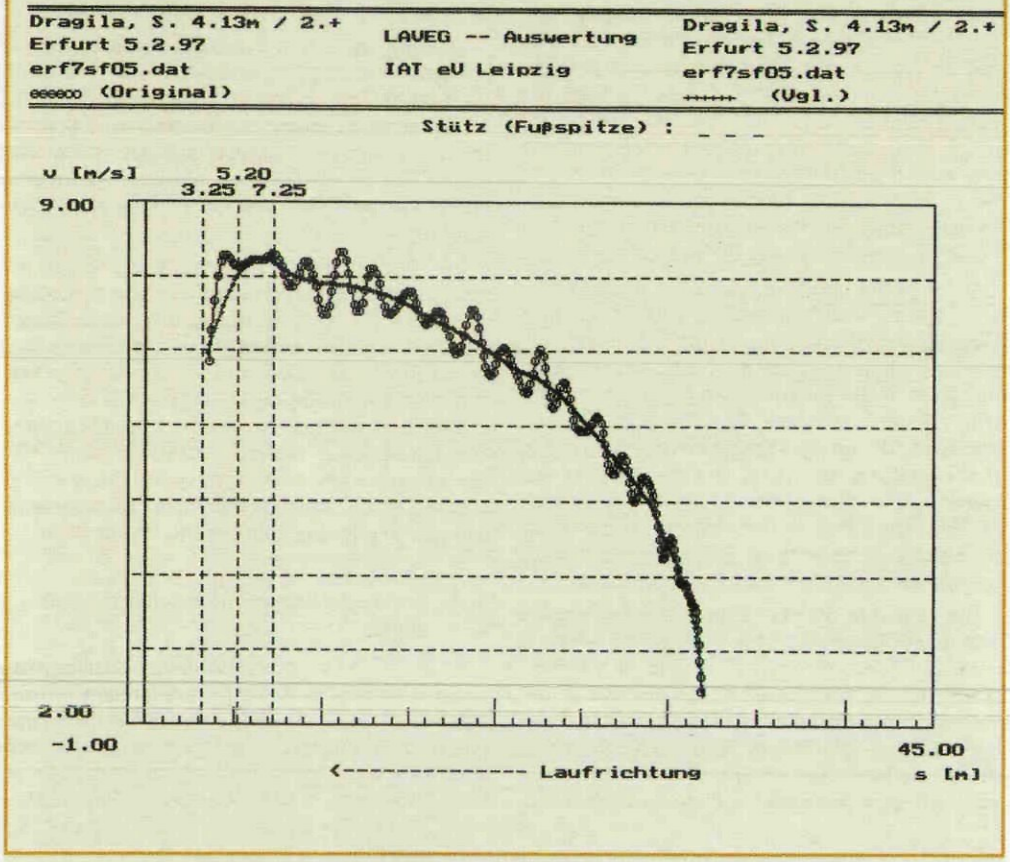


**Figure 6: Run-up velocity curve of a vault by S. Dragila (USA) over 4.13m on February 5, 1997, in Erfurt as measured by means of LAVEG (original print) in two smoothing steps**

*Explanations:*
Angaben zur Laufgeschwindigkeit = approach velocity data
absolutes Maximum der Geschwindigkeit = absolute maximum of velocity
mit dem dazugehörigen Weg = with the appropriate distance
Auswertung = evaluation
Stütz (Fußspitze) = support (tip of the foot)
Laufrichtung = running direction

development is not possible because of lack of information." (ADAMCZEWSKI/KRUBER 1993, 15). Since then the situation has changed considerably.

In March 1996 the first international medals in the women's pole vault were awarded at the European Indoor Championships in Stockholm. In 1997 this new women's event was part of the official programme of the 6th Indoor World Championships in Paris, and it will also be included in the programme of the Junior European Championships in Ljubljana and of the European Championships (sub 23) in Turku. Decisions have also been made regarding the 1998 European Championships and the Junior World Championships as well as the 1999 World Championships. Thus inclusion in the Olympic Games is the last obstacle to international recognition of the women's pole vault.

The expectation that international recognition of the women's pole would give new impetus to the accelerated development of this event (ADAMCZEWSKI/KRUBER 1993, 15) was confirmed at the World Indoor Championships in Paris (March 9, 1997). There was an obvious increase in the standard of performance: S. Dragila (USA) set a new indoor world record of 4.40m, E. George (AUS) and W. Cai (CHN) cleared 4.35m, and two additional athletes cleared 4.20m. The women's vaulting technique was also much better than in previous years.

Below is a brief analysis of the level of the women's pole vaulting technique using the 4.13m vault of S. Dragila and the 4.18m vault of W. Cai at the Indoor '97 meeting in Erfurt on February 5, 1997 as examples. These vaults are represented in *Figures 7 and 8,* using 14 and 15 characteristic and comparable positions, respectively.

### 4.1 Run-up and plant/take-off complex

*Figure 6* shows the velocity pattern of the run-up of S. Dragila's vault over 4.13m, which was measured by means of the LAVEG method using two smoothing steps. When smoothing is done to the factor of 7 the stride structure can be identified. All velocity data – including the absolute maximum velocity – are the result of smoothing to the factor of 25. For all distance data, the back wall of the box is the zero point. With a maximum velocity of 8.24m/sec at the end of the penultimate support phase before take-off and an average velocity of 8.06m/sec in the 10-5m section before the box this run-up is one of the fastest measured so far. The start of the run-up and the take-off point are 32m and 3.25m before the box respectively. Thus the run-up is 29m or 16 strides long.

We can note the similarity of stride length between the right and left leg as well as good acceleration. The run-up pattern and velocity are the strengths of the first world champion in the women's pole vault.

In her 4.18m vault W. Cai also reached a maximum velocity of 8.00m/sec at the end of the last stride before take-off and a 5m-section velocity of 7.87m/sec. The start of her run-up is 34.5m and the take-off point 3.50m before the box. Cai covers the run-up distance of 31m in 18 strides, starting with one foot in front of the other in the direction of movement.

Today the best women pole-vaulters in the world use run-ups of more than 30m and 16 to 18 strides, usually starting with one foot in front of the other in the direction of movement, with the pole held nearly or completely vertical. When setting her German indoor record over 4.17m on January 31, 1997, N. Rieger took a 16-stride run-up (BARTONIETZ/WETTER 1997, 21).

Women pole-vaulters who take 18 strides are not far off the best men pole-vaulters (at the World Championships in Stuttgart in 1993 all male pole-vaulters used 18-20-stride run-ups). Although 18 strides are still an exception in the women's pole vault, even a 16-stride run-up is an increase of as many as 2 strides in recent years.

S. Dragila, W. Cai and other elite women pole-vaulters reach their maximum velocity at the end of the penultimate stride before take-off – i.e. roughly at the beginning of the plant.

*Positions 1 to 5* in *Figures 7 and 8* represent the plant/take-off complex. W. Cai introduces the plant early enough so that at the end of the penultimate stride before take-off (*position 1*), the pole is almost horizontal, as is the case with most elite male pole-vaulters. When the thighs are parallel during the last stride before take-off (*position 2*) the upper grip hand is already above head height.

The ensuing take-off (*positions 3 and 5*) is an exemplary "free take-off", with the tip of the pole not making contact with the back wall of the box until the end of the take-off. The forward and upward extension of the whole body, avoiding any backward lean, with the upper grip hand moving only slightly behind the head, a rapid movement of the swing leg bent at an acute angle and the heel lifted close to the buttocks, are all desirable features. The take-off point is 3.50m before the box, and the last stride is only 5% shorter than the penultimate one. Her upper grip hand rises significantly immediately after the termination of the take-off (cf. *position 6*). E. George demonstrated a similar "free take-off" when clearing 4.35m in Paris (March 9, 1997).

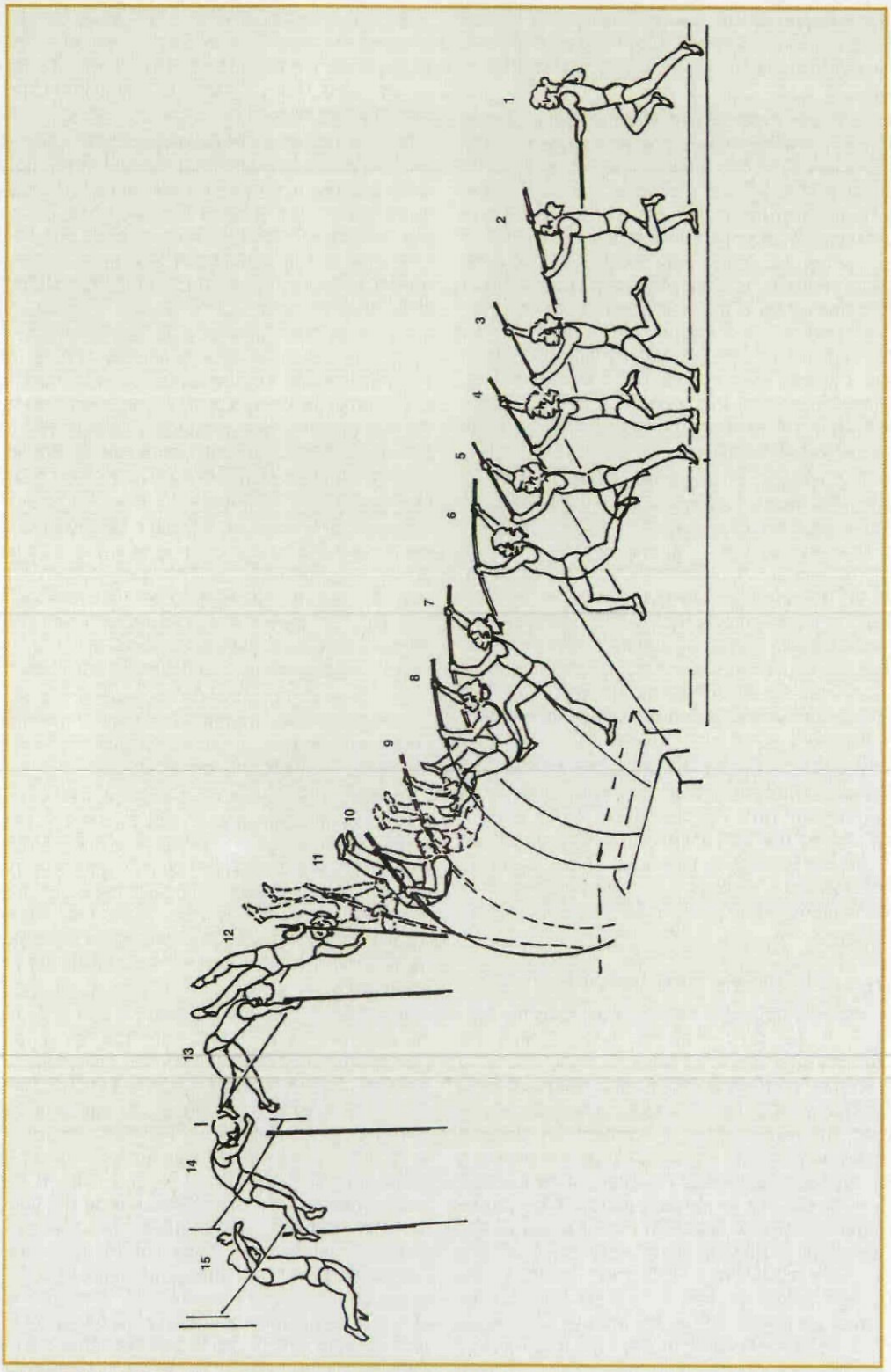


Figure 7: W. Cai (CHN), 4.18m, Erfurt, 5.2.1997, run-up speed 7.876m/sec, take-off point 3.50m

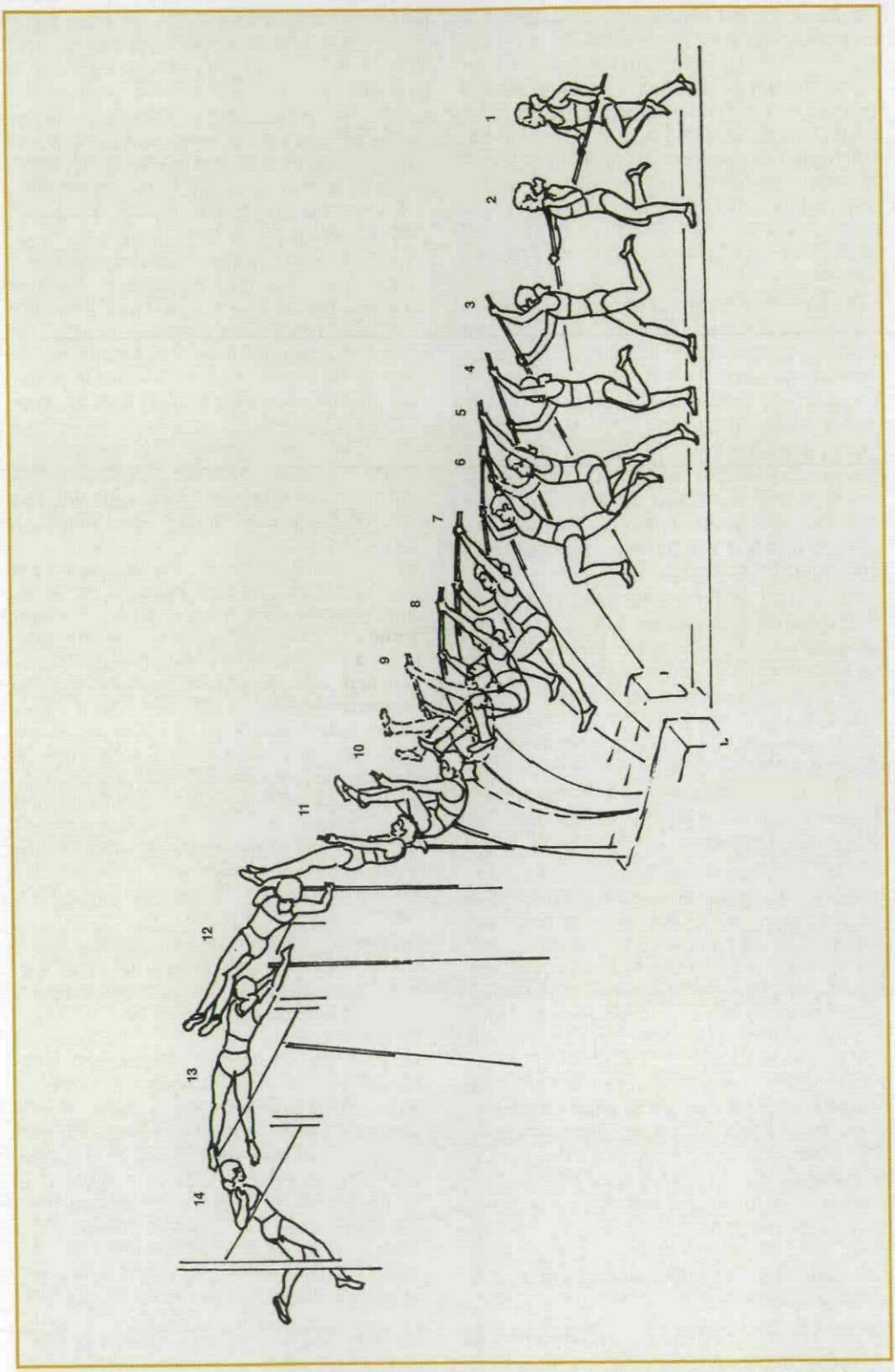


Figure 8: S. Dragila (USA), 4.13m, Erfurt, 5.2.1997, run-up speed 8.06m/sec, take-off point 3.25m

S. Dragila's vault (*Figure 8*) is characterised by a relatively late start of the plant. In *position 1* the pole is still far from horizontal, and in position 2 the upper grip hand has only reached shoulder height. The last stride of W. Cai is 5% shorter than the penultimate one. When or immediately after the jumping leg lands for take-off, the pole is planted against the back wall of the box. S. Dragila is behind the optimal take-off point by about one foot, something which FRALEY/FRALEY (1997, 17) criticise in many other American pole-vaulters.

The take-off point at 3.25m requires a marked initial bend of the pole at the take-off and results in a strong "backward pull" of the upper grip hand (*position 5*) which is even increased by the imperfect extension of the left arm (left-handed vaulter) in *positions 3 and 4*.

It is positive that even in this kind of take-off there is no significant lean-back of the trunk at the end of the take-off and that there is a "penetration" over the chest. Unlike the "free take-off", in this kind of take-off, the upper grip hand rises very slightly to *position 6*.

The multiple world record holder D. Bartová (TCH) shows an even stronger initial bend of the pole and takes off even farther behind the optimal take-off point. In her world record vault over 4.12m in Duisburg on June 18, 1995, she took off 3.05m before the box. But even in this vault she showed no backward lean of the trunk at the end of the take-off.

The current situation regarding the plant/take-off complex in the women's pole vault can be summed up as follows:

Today the "free take-off" is mastered by several female high-level pole-vaulters. However, as in the men's pole vault, there are also numerous variations of take-off with initial bending of poles to different degrees. As in the best male pole-vaulters, these variations have now reached a state of development in the world's best women pole-vaulters where they can be considered valid techniques: Like the "free take-off", these technical variations are no longer characterised by marked backward lean of the trunk at the end of the take-off. By using a considerable tension of the body, the initial bend of the pole is achieved by the chest being pushed forwards and upwards to such a degree that there is no backward lean of the trunk.

### 4.2 Later stages of the vault and bar clearance

The "later stages of the vault" include the movement phases after take-off until the release of the pole-*positions 6 to 13* in *Figures 7 and 8*.

The three medal winners from the Paris World Indoor Championships, including E. George in her winning 4.35m vault, all show the following technique in this movement phase:

- The hang phase (*position 6*) is very marked, with the take-off leg being held far back and maintaining tension. In this way the prerequisites of an effective swing of the leg are satisfied. All vaulters perform this leg swing with an extended leg (*positions 6 to 8*).

  These technical elements show definite progress as compared to previous years, and their are vital for the ending of the pole is to bend the pole. However, during and even after the long leg swing, all three athletes, unlike the men of the Russian pole vault school in particular, do not open the elbow angle of the forearm.
- On maximal bending of the pole, the pelvis has reached or passed shoulder height. With the initial vertical extension of the body, the legs are pulled backwards to the upper grip hand (*position 10*).

  However, unlike the men, the women do not yet manage to pull their knees to the upper grip hand. All three athletes reach an almost vertical extension of the body before the upper arm starts to pull or flex (*position 11*).

  Although all three athletes show potential for improvement with regard to vertical alignment, body tension (Cai) or a bending of the lower legs towards the bar (Cai/George), all vertical work on the pole up to this point no longer resembles the compromise solution of a simultaneous execution of the arm pull and hip movement demonstrated by many women and girls. Sufficient pole bend is required for this new technique in order to benefit from optimal pole extension.
- The ensuing turn and pull into extension (*position 12*) is a technical element in which women's standards have also improved, although there are individual deviations from the vertical direction.

  At the release of the pole (*position 13*) – the hips of W. Cai and S. Dragila have reached their highest point. This means that – in contrast to the best male pole-vaulters – Cai and Dragila do not raise their centre of mass further after the release of the pole. When analysing the world indoor record vault over 4.11m of the Chinese C. Sun in Pulheim (February 3, 1995) Grabner (1996, 44) even observed a slight lowering (-0.3m/sec) of the centre of mass. When they push off from the pole W. Cai and S. Dragila are already clearing the bar. After releasing the pole, the hips begin to cross the bar and lower at the same time.

  As yet E. George is the only female athlete who

demonstrates a new, even better technique of pushing off from the pole and clearing the bar. As she releases the pole, her hips are still below or just at the same height as the bar and only her lower legs have crossed the bar. This means that the bar is cleared in the form of a free flight, with the centre of mass as well as the hips having to rise much higher in order to avoid knocking off the bar. In this context, the fact that E. George's body position over the bar is not ideal and could be considerably improved is of secondary significance.

Today the best female pole-vaulters in the world master at least the basic structure of all main technical elements of the later stages of the vault. This means that their techniques do not deviate from the rough model. To a greater extent than in the past, the whole technique is aimed at a deliberate bending of the pole and better utilisation of the pole extension. Even the differences between vaulting height and grip height (minus a box depth of 0.20m) prove that here there are considerable individual technical variations and potential for improvement.

In her clearance of 4.45m, the difference between the vaulting height and grip height of E. George was 0.55m, and for W. Cai's clearance of 4.33m it was 0.45m (Bartonietz/Wetter 1997, 22). This means that the grip heights of these athletes were 4.10 and 4.08m respectively. When setting her German indoor record of 4.17m (January 31, 1997) N. Rieger's grip height was also 4.10m, but her vaulting-height/grip-height differential was only 0.27m (Bartonietz/Wetter 1997, 22). On June 21, 1996, N. Ryshich set a world junior record in Cologne of 4.15m with a grip height of 4.20m and a vaulting-height/grip-height differential of 0.15m. The grip height of 4.20m is 81.5% of the grip height of 5.15m reached by male pole-vaulters. This means that even the greatest women's vaulting-height/grip-height differential of 0.55m is only 45.8% of the men's differential of 1.20m.

This discrepancy is not only an indication of the scope for technical improvement of the women in the later stages of the vault, but also emphasises the particular importance of trunk and arm strength for the women and their deficiencies in this area, especially as trunk strength is already known to be women's weakest strength area.

## 5 Conclusions

(1) Ongoing measurement of the run-up velocity during competition and training is and will remain an important part of the monitoring of performance development in the pole vault. In this way, the sex and age-specific description and assessment of the connection between run-up velocity and pole vault performance identifies new and improved prerequisites and at the same time is a practical and handy "tool" for both coaches and athletes.

The present guidelines should be checked and updated in each Olympic cycle – i.e. at 4-year intervals. Currently, in the women's pole vault, shorter intervals could also prove worthwhile or necessary in order to keep up with the rapid development of this young event.

(2) Furthermore, the time measurement in two 5m sections of the approach has proven worthwhile for the routine measurement of the approach velocity. Suitable places for the light barriers are 16, 11 and 6m before the back wall of the box in the men, 15.5, 10.5 and 5.5m in male youth athletes and 15, 10 and 5m in all women's age groups.

The laser distance measurement (LAVEG) has been developed as a method for the determination of the course of the run-up velocity and for the production of further information about the run-up. Measurement without the use of a reflector and the evaluation and presentation of the results have proven very useful for the pole vault and have been included in the research.

(3) In all age categories of the men's and women's pole vault, the run-up velocity is an important factor affecting performance. In the women's pole vault there is even greater potential for improvement in this area than in the men's pole vault and in the other athletic events.

In the next ten years, run-up velocities of 8.5m/sec seem possible in the women's pole vault. However, a faster run-up calls for higher grips and stiffer poles. Otherwise, an improvement in performance will not be achieved.

As far as the run-up velocity is concerned, the German women pole-vaulters have managed to keep up with the best in the world.

(4) Regarding the pole vault technique as a whole, the best women pole-vaulters in the world have got closer to the men's technical model. The take-off is mastered in the form of a "free take-off" or at least without a backward lean of the trunk. The hang phase is very marked, the long swing of the leg is performed with an extended leg, and the hips are brought up to or beyond shoulder height during the rock-back. In spite of equally significant technical progress there is still potential for improvement, especially in the

vertical work on the pole and the bar clearance. This means that the special strength of the trunk and arms is becoming a crucial factor in determining performance.

German vaulters have technical deficiencies compared to the current best athletes in the world. They are also 0.28cm behind the best in the world in their vaulting height/grip height differential.

(5) The international recognition of the women's pole vault which is currently taking place, and the resulting enhancement of its status, are essential for the further rapid development of this young event.

Taking in to account the great significance of the trunk and arm strength in the pole vault, as well as women's known weakness in this area, grip heights of 4.35 to 4.45m and vaulting height/grip height differentials of between 0.65 and 0.75m – and thus vaulting heights of between 4.80 and 5.00m – are realistic targets for the next ten years.

## References


ADAMCZEWSKI, Horst; DICKWACH, Hartmut (1991):
Zum Zusammenhang zwischen Anlaufgeschwindigkeit und Sprungleistung. In: Die Lehre der Leichtathletik 19, pp. 15-18

ADAMCZEWSKI, Horst; KRUBER, Dieter (1993):
Technische und konditionelle Aspekte des Stabhochsprungs der Frauen. In: Die Lehre der Leichtathletik 15-16

BARTONIETZ, Klaus; WETTER, Jochen (1997):
Technikeinschätzung des 4,17-m-Stabhochsprunges von Nicole Rieger. In: Die Lehre der Leichtathletik 21-22

DICKWACH, Hartmut; HILDEBRAND, Falk; PERLT, Bettina (1994):
A laser velocity measuring device. New Studies in Athletics 4, pp. 31-40

FRALEY, B.; FRALEY, D. (1997):
Stabhochsprung. Die Lehre der Leichtathletik 7-11, pp. 15-24

GRABNER, Stefanie (1996):
Kinematische Analyse des Stabhochsprungs der Frauen. Diplomarbeit an der DSHS Köln

GROS, Volker; KUNKEL, Volker (1988):
Biomechanical analysis of the pole vault. In: Brüggemann, G.-P.; Susanka, P. Scientific Report on the II. World Championships in Athletics Rome 1987

GROS, Volker; KUNKEL, Volker (1990):
Biomechanical analysis of the pole vault. In: Brüggemann, G.-P.; Glad, B. Scientific Research Project at the Games of the XXIVth Olympiad – Seoul 1988


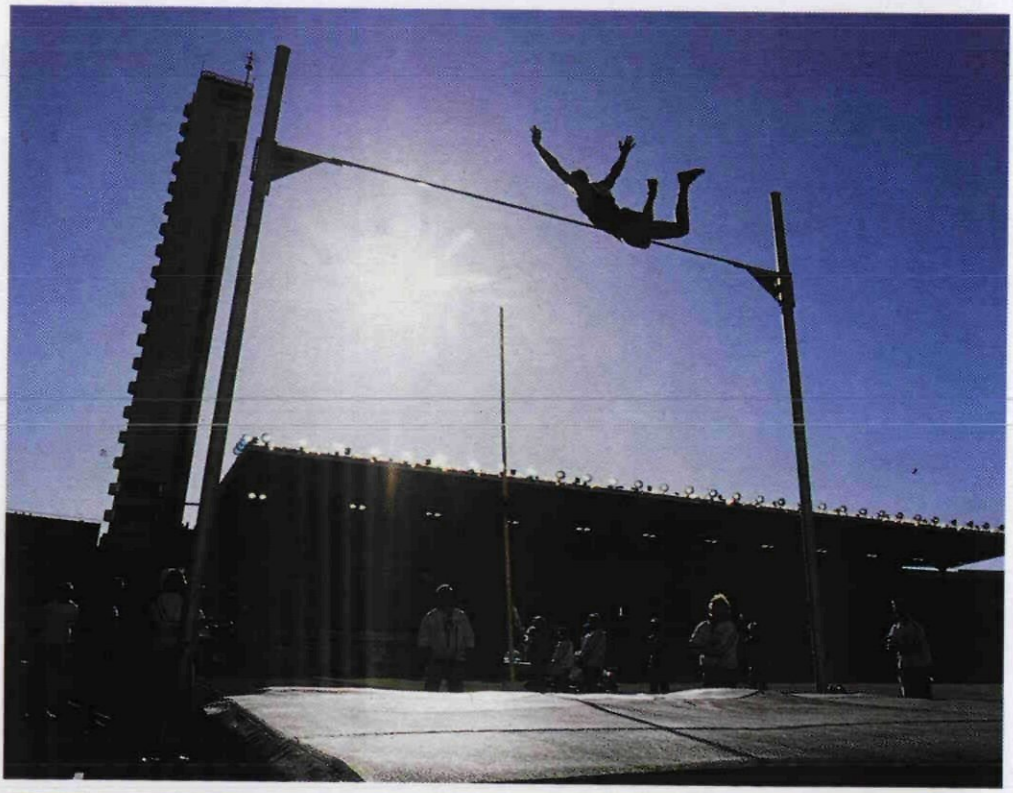

Photo: Allsport / Bob Martin