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# INFLUENCE OF SELECTED KINETIC PARAMETERS IN FEMALE POLE VAULT ON SPORT PERFORMANCE

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**ABSTRACT.** Pole vault is the only athletic event in which the performance is reached with use of tool. From the point of technique it is considered like complex athletic event. The movement activity is realized in two basic parts; the first is approach ended with take-off and the second are movements of jumper on the pole. In the contribution we try to reveal hierarchy of kinetic parameters of competitive movement activity and their influence on the level of female pole vault sport performance. There are involved 19 female pole vault jumpers with sport performance 380 – 483 cm, divided on 2 different groups from the point of sport performance level (lower sport performance group and higher sport performance group). In this contribution are used logical methods, mostly analyse, comparison and induction. Differences between those two groups are mostly found in speed and angles parameters during pole vault jumping. Group of higher sport performance level loses less of horizontal speed of centre of gravity and of higher arm grip in phase of take-off and keep higher vertical speed of centre of gravity in phases end of the extension with turn and in end of the lift. Jumpers of higher performance level reached more favourable values also in some angle parameters; it was mostly in angle of take-off tread-down, climbing angle and angle between fore arm of lower upper extremity with the pole at moment of take-off end. In the work on pole we also found between our groups in watched angle parameters significant differences. In the group of female lower performance level jumpers comes to considerable centre of gravity body move away from extension axis. Too great centre of gravity move away at extension end is the course of minimal, resp. zero growths on maximal centre of gravity height during last phase of jump. Found differences in speed and angle parameters in female pole vault jumping manifest better mastering of movement activity mainly in phases take-off and in work on pole of higher level sport performance group. Presented differences of these two watched groups of female pole-vaulters show on possibilities and training orientation for further performance increase.

***Keywords:*** *female, pole-vault, kinematic parameters, speed, angles*

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## Introduction

Pole vault is the only athletic event in which is result reached with the help of tool. This pole use courses its withdrawal far from any fundamental locomotion and classifies it among complex athletic events. Movement activity of it is performed in two basic parts. First is an approach finished by take-off and second is a phase of actual jump – activity of jumper on pole. An approach has cycle movement structure and it is affected by handling and bearing of pole by both upper extremities with pole transmission at the end of approach. Movements on pole have on the contrary acyclic character and represent structure of forward movements in frontal and vice versa position at parallel rotations round horizontal and also vertical body axes and round the pole performed in optimal time sequence – rhythm.

Sport performance in pole vault depends on a reach height of the centre of gravity of pole vault jumper body during the jump and on the economy over the bar transition.

Very important precondition for high performance result is to reach during approach as high velocity as possible, mainly at the end of approach and finish this approach with explosive take-off and with rational transition on the pole. McGinnise (1997) proves that take-off effectiveness is manifested in holding or even in increase of kinetic energy gained with approach. Approach velocity and take-off form kinetic energy which pole-vaulter by exact and energy planting the pole in the take-off box transmits on the pole. At take-off moment the pole starts to bend and thus is shortened the distance between grip and the end of the pole. Pole elasticity thus enables actually to pass easier and faster through vertical line and this also enables to have higher grip on the pole. The pole in the phase of bending cumulate kinetic energy and at period of straightening phase returns it at vertical centre of gravity acceleration of pole-vaulter. At time of pole straightening is important active muscle pole-vaulter work, for direction of catapulting must be the same with direction of the pole-vaulter centre of gravity; otherwise it comes to force breakdown and it courses loss of peak height of the centre of gravity (CGv). The pole-vaulter by his activity on the pole influences common movement rhythm of movement; through his adequate activity on pole can be increased vertical centre of gravity peak.

For technique evaluation we need biomechanics analyse in order to evaluate more precisely technique of movements, enables to identify differences from ideal technique model and thus even form orientation its further improvement. At sportsmen technique evaluation we start from mechanic phenomena that are in biomechanics called biomechanical characteristics. These phenomena make sportsman movement technique more concrete in its kinetic and dynamic manifestation and they can be measured and evaluated. The more complex movement activity is, the more needed and helpful can biomechanical analyse be.

Kinematical analyse enables to learn movement activity character and thus is formed prerequisite for following movement rationalization. Lately took care with kinematical analyse use of competitive movement activity in athletic events several authors (Bojko & Nikonov, 1989; McGinnis, 1997; Grabner, 1997; Varga, 1997; Krška & Koštial, 2000; Koštial & Dremmelová, 2001; Krska, 2008); they show mostly on its contribution on training process improvement.

In the sport performance structure of female pole-vaulters those speed and angle characteristics (fig 1) of movement activity play very important roles (Krška, 2008).

## Objectives

Aim of this contribution is to analyse course of horizontal and vertical centre of gravity speed and to select angle characteristics of competitive female pole vault-jumpers movement activity and reveal their influence on sport performance level.

Tasks:

1. Realise kinematic analyse of jumps of watched female pole vault jumpers,
2. From the hierarchy of sport performance structure model (Krška, 2008) select positions of proper speed and angle characteristics,
3. Analyse and compare gained kinetic parameters of female pole-vaulters of different sport performance levels and try to explain their mutual relations and their influence on the level of sport performance.

## Material and methods

This research was performed in 2004 - 2006 on the meetings Golden spiked shoes in Ostrava, Czech Republic. Kinetic parameters were gained by two-dimension analyser Consport Motion Analysis System (CMAS). There are involved 19 female pole-vaulters with the sport performance 380 – 483 cm. All watched top-level female pole-vaulters (group S) were divided on 2 smaller groups; lower sport performance group (S1) and higher sport performance group (S2). In this contribution are used logical methods, mostly analyse, comparison and induction.

## Results and discussion

Fundamental statistical characteristics of our female pole-vaulters can be seen in tables 1, 2 and 3. Figure 1 shows us the hierarchy of sport performance structure of female pole vault with mutual relations of watched speed and angle parameters within single factor levels.

### *Speed parameters*

Graphical courses of watched vertical and horizontal speed parameters can be seen in figures 2, 3 and 4.

Average horizontal centre of gravity (CGv) speed of our female pole-vaulters at the beginning of last step reached 7.27 $m.s^{-1}$ (fig 2). At the first touchdown moment of take-off the velocity even slightly increases on average value 7.46 $m.s^{-1}$. The fastest (8.48 $m.s^{-1}$) is always the one with the best sport performance result, S.D. (483 cm). During take-off reached pole-vaulters average loss of velocity 1.02 $m.s^{-1}$. Better value about technique effectiveness seems to be percentage loss of vertical CGv speed during take-off; average value is minus 13.4 % from the velocity reached during approach. After transmission on pole we can watch relatively high values of CGv horizontal speed at moment of end of hanging position (average value is 6.00 $m.s^{-1}$). At the moment of the end of swing up we watch their average velocity on the level 4.09 $m.s^{-1}$.

Like supported parameter of pole-vaulter transmission on pole we watched horizontal speed at the point of upper arm grip that during take-off suddenly decrease of 3.56 $m.s^{-1}$ (fig 3). This average loss in percentage is 49.4 %.

During pole-vaulter activity on pole is important gained vertical CGv speed (fig 4). First values are registered after the end of take-off when average vertical CGv speed reaches average value 1.20 $m.s^{-1}$. During following phases of hanging position, swing up and roll this value changes only slightly and have oscillating character. Considerable growth of vertical speed of the CGv can be watched after beginning of pole extension. After the end of extension phase, pole-vaulters reach an average value 3.51 $m.s^{-1}$. At the moment of peak height, the average vertical speed value is on the level 3.16 $m.s^{-1}$.

The average horizontal CGv speed of higher sport performance pole-vaulters (S2) slightly overreaches values reached by pole-vaulters of lower sport performance (S1). The highest difference can be watched at the moment of take-off end (average is 0.62 $m.s^{-1}$), when pole-vaulters S2 lost from horizontal CGv speed during transmission on pole only 0.74 $m.s^{-1}$, while S1 lost 1.33 $m.s^{-1}$ (fig 2).

Similar course with only slightly different values can be watched (fig 3) also at horizontal speed of upper arm grip. The most comprehensive difference between our groups are watched at moment of the end of take-off (difference is

1.41 $m.s^{-1}$), when in group S2 we watched average speed 4.28 $m.s^{-1}$ and in group S1 2.87 $m.s^{-1}$. The difference at speed loss of upper arm grip during the whole take-off period is even slightly higher and represents average value 1.57 $m.s^{-1}$.

Higher values of vertical CGv speed we found in the group of higher sport performance level (S2). The group of lower sport performance level (S1) reached higher velocity only at moment of hanging position (difference plus 0.40 $m.s^{-1}$) that we consider like not effective (fig 4). Significant difference in average value it is 0.72 $m.s^{-1}$ in favour of S2 group that can be watched at the end of roll and 0.56 $m.s^{-1}$ at the end of extension that shows on better work on pole of higher sport performance pole-vaulters (S2).

***Angle parameters***

In fig 1 we can see an importance of angle parameters in sport performance pole vault structure. From this point the decisive are operating angle and climb angle (u54 and u55); other 4 parameters (u52, u53, u56 and u57) belong to supported substructure factors. Positive influence on the 1st performance factor level we stay at operating angle of take-off on clean grip height (parameter of condition character) and at climb angle of the CGv in standing over (peak height) that is parameter of technique character). Mutual comparison of our watched groups S1 and S2 can be seen graphically in figures 5, 6, 7.

Average values of selected angle characteristics learned during take-off activity differ only slightly (fig 5). At tread-down of take-off angle we watch more active take-off action by higher performance jumpers S2 ($71.90^0$) comparing with lower performance group S1 ($68.60^0$). Following take-off angle is at higher performance group (S2) lower of $3.70^0$ like at jumpers S1; this shows on more effective take-off end connected with better pole squeeze. Average value of operating angle is in both groups very similar – $34.4^0$ at S1 and $34.8^0$ at S2. Lower average climb angle at S2 like at S1 also shows on better transition on pole in the group of higher sport performance female jumpers.

During quality evaluation of transition on pole of female jumpers we watched position (angle) of forearm of lower upper extremity to the pole (fig 6). At take-off end we found in the group S1 angle $121.70^0$ and in S2 $103.30^0$; it shows on better arms position in the group of higher sport performance female jumpers. At the end of following phase of hanging position we watch in the group S1 slight improvement of lower arm work and angle decrease of $1.80^0$ on $119.90^0$. On the contrary in the group S2 we found slight angle increase of $4.30^0$ on $107.60^0$; in spite of this decrease of difference it this proper arm position between our groups, we still consider our group S2 in this angle significantly better like it is in S1 (difference $12.30^0$).

Effectiveness of activity on pole of female jumpers can be also estimated by watching of body position from vertical line on the surface during phases of pole extension (fig 7). In the first comparison in the moment of extension phase end we watch at female jumpers S1 angle 26.90$^0$ and in S2 more favourable angle 16.50$^0$. During phase extension with turn happens in both groups to move away of the CGv from the pole. Average angle increase in S1 is 24.70$^0$ and it represents its growth on 51.60% and in S2 is increase on 16.40$^0$ and it means its increase on 32.90%. At the end of lift when female jumpers leave pole and they get into last phase of bar clearance we watch significant angle growth that confirm move away of the centre of gravity from the pole. In S1 it is in average 80.00$^0$ and in S2 it is 65.80$^0$. These reached values are courses of unwanted low resp. zero increase in the height of the CGv during last phase of the jump.

**Tab 1.** Statistical characteristics of kinetic parameters of the whole group **S**, sport performance 380-483 cm (S, n = 19)

| *Parameter (u)* | | [unit] | x | $x_{max}$ | $x_{min}$ | s |
|---|---|---|---|---|---|---|
| *u1* | Maximal centre of gravity height | [cm] | 448,03 | 490,50 | 408,10 | 23,07 |
| *u2* | Absolute height of upper arm grip | [cm] | 403,11 | 420,00 | 385,00 | 10,86 |
| *u3* | Standing over (peak height) | [cm] | 44,92 | 70,50 | 11,20 | 16,24 |

**Tab 2.** Statistical characteristics of kinetic parameters of the lower sport performance group **S1**, with sport performance 380-430 cm (S1, n = 9)

| *Parameter (u)* | | [unit] | x | $x_{max}$ | $x_{min}$ | s |
|---|---|---|---|---|---|---|
| *u1* | Maximal centre of gravity height | [cm] | 428,36 | 441,14 | 408,10 | 12,28 |
| *u2* | Absolute height of upper arm grip | [cm] | 395,89 | 406,00 | 385,00 | 6,81 |
| *u3* | Standing over (peak height) | [cm] | 32,47 | 49,10 | 11,20 | 10,83 |

**Tab 3.** Statistical characteristics of kinetic parameters of the higher sport performance group **S2**, with sport performance 440-483 cm (S2, n = 10)

| *Parameter (u)* | | [unit] | x | $x_{max}$ | $x_{min}$ | s |
|---|---|---|---|---|---|---|
| *u1* | Maximal centre of gravity height | [cm] | 465,73 | 490,50 | 449,30 | 13,98 |
| *u2* | Absolute height of upper arm grip | [cm] | 409,60 | 420,00 | 395,00 | 9,79 |
| *u3* | Standing over (peak height) | [cm] | 56,13 | 70,50 | 33,30 | 11,35 |

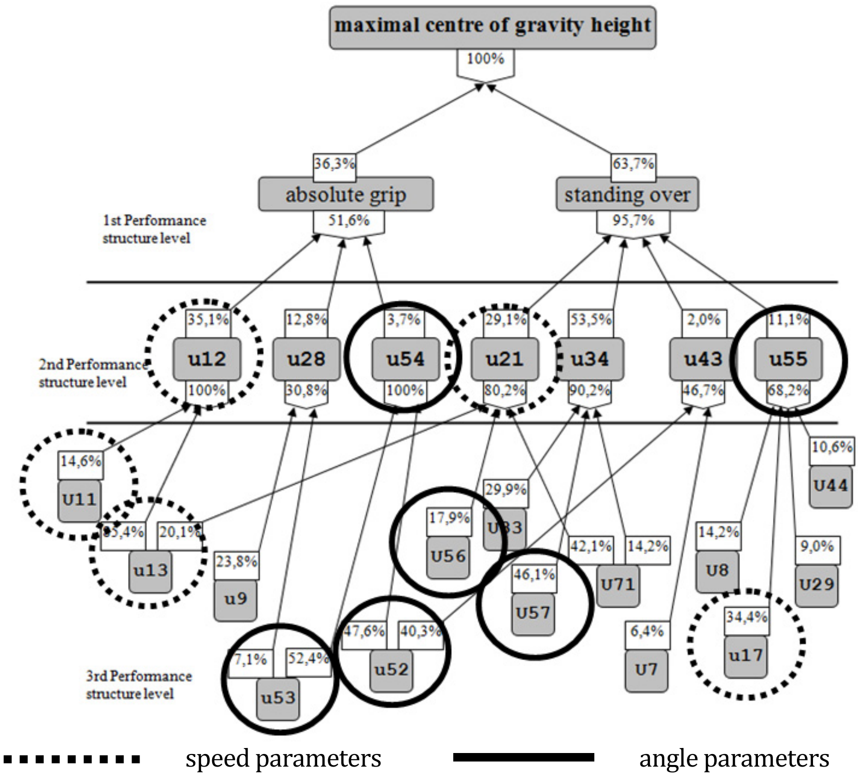


**Fig 1.** Relations and quantifications of parameters in female pole vault sport performance structure with regard of speed and angle parameters (Krška, 2008)

*Legend:*

| | |
|---|---|
| *Horizontal speed of centre of gravity at moment* | |
| *u11* | tread-down of take-off |
| *u12* | end of take-off |
| *u13* | speed lost during take-off |
| *Vertical speed of centre of gravity at the end of moment* | |
| *u17* | end of hanging position |
| *u21* | end of extension with turn |
| *Angle Parameters (u)* | |
| *u52* | angle of tread-down of take-off |
| *u53* | angle of take-off |
| *u54* | operating angle |
| *u55* | climb angle |
| *u56* | angle between body and vertical line at moment of extension end |
| *u57* | angle between body and vertical line at end moment of swing-up with turn |

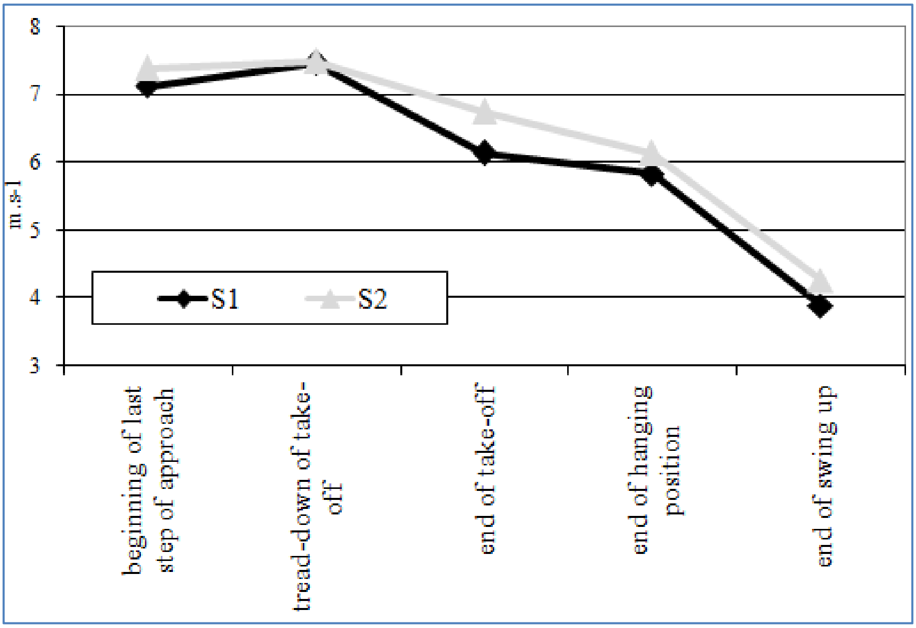


**Fig. 2.** Course comparison of horizontal speed of centre of gravity

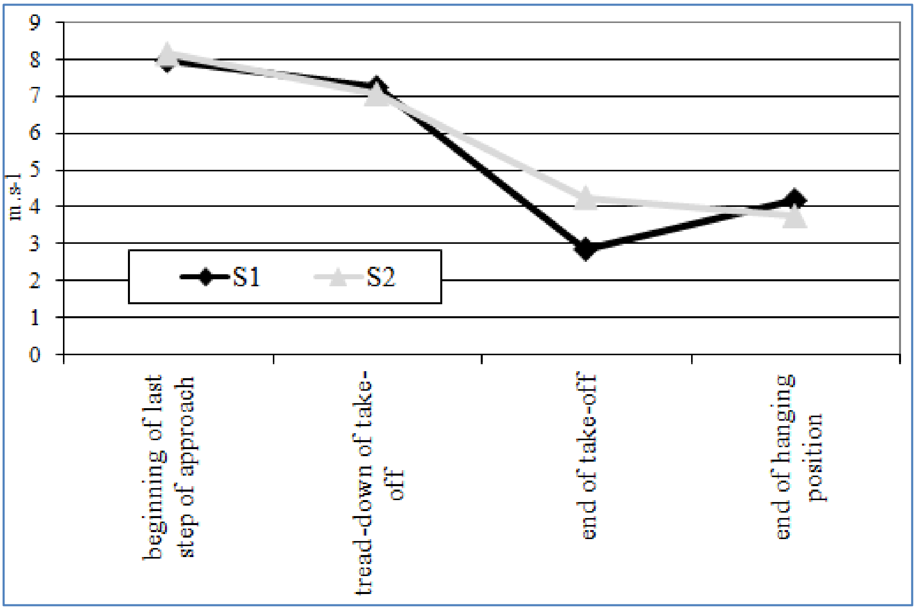


**Fig. 3.** Course comparison of horizontal point speed of higher arm grip

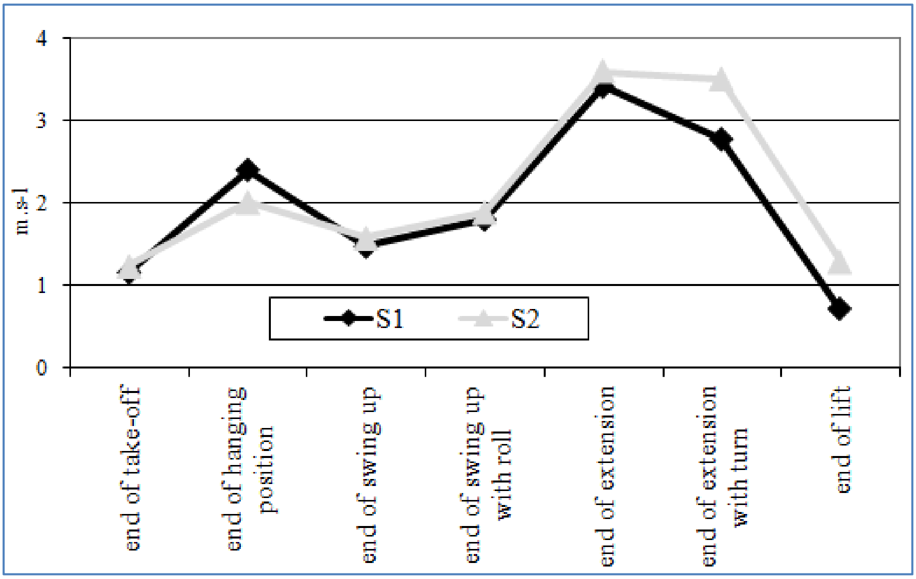


**Fig. 4.** Course comparison of vertical speed of centre of gravity

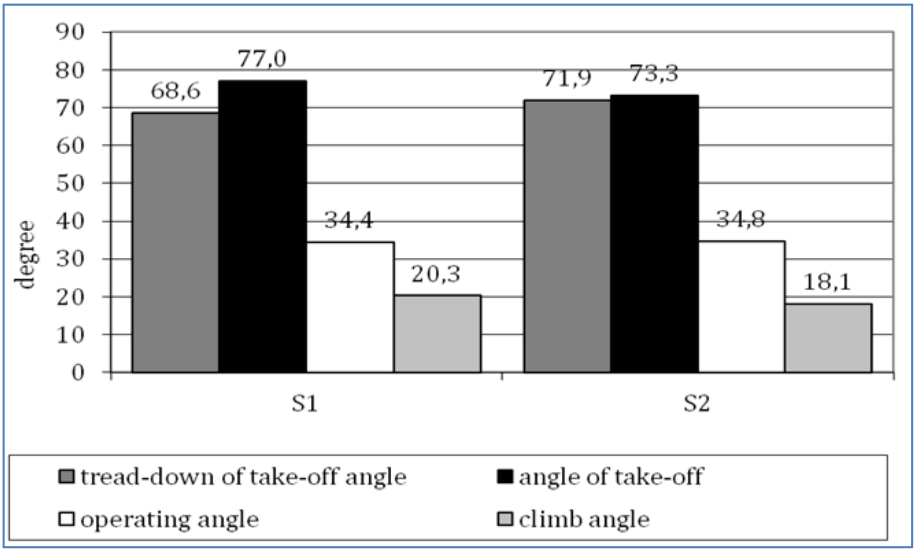


**Fig 5.** Angle comparisson during contact phase of take-off
in groups of female pole-vaulters

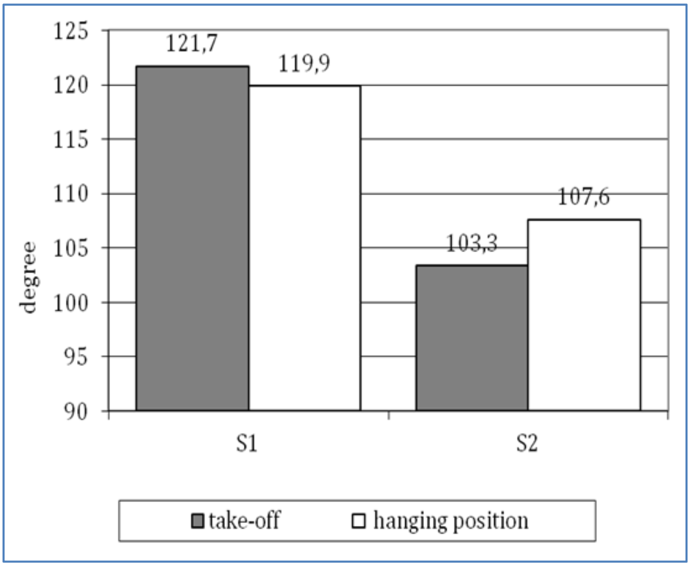


**Fig 6.** Angles comparison between fore-arm of lower upper extremity and pole at moment of end of take-off and hanging position phases in female jumpers

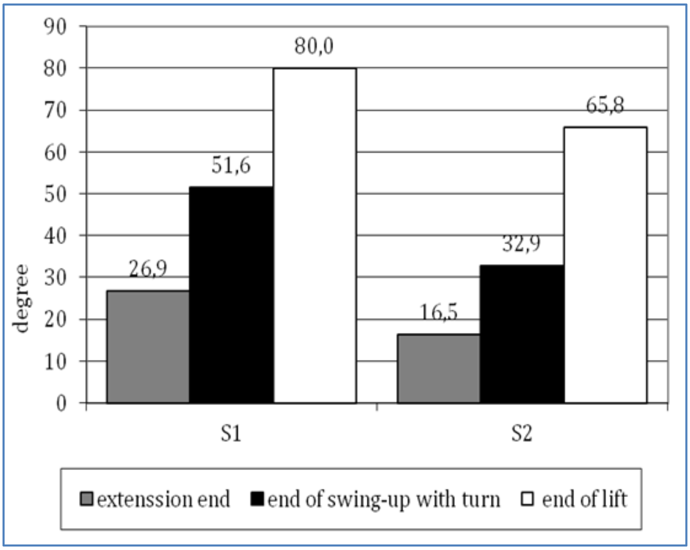


**Fig 7.** Body angles comparisson to vertical line on surface at finishing of selected phases

## Conclusions

1. Our group of higher sport performance level reached in phase transmission on pole favourable values in horizontal centre of gravity speed at moment of the end of take-off and parallel watched loss during take-off phase and in angles of take-off tread-down, climb angle and angle between fore-arm of lower upper extremity with the pole at take-off moment end.

2. Better activity on pole of again higher sport performance pole-vaulters is manifested by higher vertical speed at the end of phases of extension with turn and lift. In the group of female lower performance jumpers comes to considerable centre of gravity body move away from vertical axis; thus angles between body and vertical line at phases extension, extension with turn and lift are too great and centre of gravity moves away from vertical axis and it results to minimal, resp. zero growths of centre of gravity height during last phase of jump.

There are two speed parameters (horizontal CGv velocity at the end of take-off and vertical CGv speed at the end of extension with turn) and two angle parameters (angle in take-off and climb angle of CGv) that influence directly parameters on the 1st sport performance factor level which are of condition resp. technique character.

***Effective transmission on pole is enabled and mostly characterised by:***

*Speed parameters:*

1. Horizontal CGv speed at moment of the end of take-off,
2. Velocity loss during take-off phase.

*Angle parameters:*

1. Operating angle in take-off,
2. Climb angle of centre of gravity,
3. Angle of take-off tread-down,
4. Angle between fore-arm of lower upper extremity with pole at moment of take-off end.

***Effective work on pole is conditioned and characterized by these parameters:***

*Speed parameters:*

1. Vertical speed at the end of phases of roll,
2. Vertical speed at the end of extension with turn.

*Angle parameters:*

1. Angle between fore-arm of lower upper extremity and pole at moment of hanging position end,
2. Angle between body and vertical line at moment of extension end,
3. Angle between body and vertical line at end moment of swing-up with turn,
4. Angle between body and vertical line at end moment of lift.

Found differences in speed and angle parameters between those two sport performance different level groups enable us to evaluate precisely individual female pole vault technique with further technique training specification and final sport performance level improvement.

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