QUANTITATIVE ANALYSIS OF TRUNK LEAN DURING THE TAKEOFF PHASE OF FOSBURY FLOP HIGH JUMPERS OF ELITE INDIAN ATHLETES

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Abstract— **A high jump can be divided into three parts the run-up phase, the take off phase and the flight or bar clearance phase. The importance of the run-up is to set the appropriate conditions for the beginning of the take off phase. during the take off phase, the athlete exerts forces that determine the maximum height that the centre of mass will teach after leaving the ground and the angular momentum (also called "rotary momentum") that the body will have during the bar clearance.**

In a fosbury flop the rotation consists of a "twist" (a rotation around the longitudinal axis of the body) which turns the back of the athlete toward the bar, and a "somersault" (a rotation around a transverse axis) which makes the shoulders go down and the knees go up (Dapena, 1988). The combination of these two motions produces a twisting somersault to rotation which leads to a face up layout position at the peak of the jump. Combined with arched configuration of the body, this position allows the athlete to clear a bar set at a height that is near the maximum height reached by the centre of mass (Dapena 1980a.1980b).

Somersault rotation can be broken down in to two parts a forward somersaulting component and a lateral somersaulting component. During the takeoff phase the athlete produces angular momentum about a horizontal axis perpendicular to the final direction of the run-up. This is called the forward somersaulting angular momentum. In the last step of the run-up the high jumper thrusts the hips forward and this makes the trunk have a backward lean at the start of the takeoff phase (i.e. at touchdown the instant when the takeoff foot lands on the ground). Then the trunk rotates forward during the takeoff phase and is vertical at the instant that the foot leaves the ground.

The curved run-up used in the fosbury flop style of high jumping makes the athlete lean toward the centre of the curve. This helps the jumper to lower the centre of mass in the last steps of the run-up. It also allows the athlete to rotate during the take off phase from an initial position in which the body is tilted toward the centre of the curve to a final position in which the body is essentially vertical. Therefore it allows the athlete to generate rotation (lateral somersaulting angular momentum) without having to lean excessively toward the bar at the end of the takeoff. Therefore the purpose of this study was to analyze the trunk lean during the takeoff phase of elite Indian male athletes during their competitive performance.

The take off phase is defined as the period of time between the instant when the take off foot first touches the ground (touchdown) and the instant when it loses contact with the ground (take off).

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Methodology

Subjects:

Five male high jumpers were filmed during their competitive performance in the National open athletics championship from 10th September to 13th September, 2012 held at Jawaharlal Nehru stadium, Chennai, India. The best valid and failed jumps were taken from each fosbury flop right leg takeoff athlete for the further analysis.

Tools and equipments:

Biomechanical analysis requires specific tools and equipment to capture and analyze the data. The experimental apparatus used in this research work were two Panasonic-AG-DVX-102B, F11 sensitivity, high image quality, camcorders, measuring tape and the Quintic Biomechanics v21 motion analysis software and computer system.

Collection of data and filming protocol:

For the collection of kinematical trunk lean data two Panasonic camcorders was mounted at a distance of ten meters at height of five feet above the ground. First camcorder was mounted for back view at left standard line for right foot takeoff high jumpers. The second camcorder for side view was mounted in front of the crossbar with a distance of 15 mts. First camera used for capturing the video clippings of lateral trunk tilt and second camera used for capturing the video clippings of backward trunk tilt. Two camcorders captured the video clippings of Fosbury flop jumper's last stride. All the attempts of the selected subjects were recorded during the competition. When they cleared the bar on a particular height was taken as successful jump and when they were unable to clear the bar at a particular height was taken as failed jump.. Analysis was conducted using the quintic biomechanics V 21 (motion analysis).The angles of the trunk tilt variables which were selected in this study were 1) backward/forward trunk tilt during the take off phase 2) left/right trunk tilt during the take off phase.

Angle of tilt of the trunk during the take off phase variables were backward/forward at the start of the take off phase (BFTD),and end of the take off phase(BFTO) and the change in the angle during the take off phase(ΔBF)

Angle of tilt of the trunk during the take off phase variables were left/right at the start of the take off phase (LRTD) and at the end of the take off phase (LRTO) and the change in this angle during the take off phase (ΔLR).

Acquired data were subjected to statistical analysis by t test for comparison of the angle of trunk lean between successful and unsuccessful jumps. All statistical procedures were conducted using the SPSS software. A level of significance was set at 0.05.

Analysis

The raw data were arranged separately, tabulated and subjected for the descriptive statistical analysis, followed by t test by using SPSS to distinguish if there were any differences across the different parameters between successful and failed jumps. The researcher reached at the results of this empirical investigation which is presented by the respective tables and graphs

Table 1. Anthropometric measurements of the athletes and their best performance.

Athletes	**Age**	**Height (cm)**	**Leg length (cm)**	**Training age (yrs)**	**Weight (kg)**	**Best performance in high jump (cm)**
Rithesh kumar	22	180	90	5	62	195
Harshith.S	18	189	99	2	62	216
Arun kumar	22	183	98	3	66	200
Amarnath ojha	19	187	102	2	64	195
K.Gowtham	22	180	93	5	65	205
MEAN	**20.6**	**183.8**	**96.4**	**3.4**	**63.8**	
SD	**1.74**	**3.66**	**4.32**	**1.36**	**1.60**	

The data indicates that the averages age of the male athletes was 20.6 years with an average height of 183.8cm, average leg length was 96.4 cm and training age was 3.4 years and average weight was 63.8 kg. Among the five subjects Harshith has shown the highest performance of 216 cm.

Table :2 Trunk lean angles during the take-off phase between success and failed jumps.

Variable		**Rithesh kumar**		**Harshith.S**		**Arunkumar**		**Amarnath**		**K.Gowtham**	
		Success	**Fail**	**Success**	**Fail**	**Success**	**Fail**	**Success**	**Fail**	**Success**	**Fail**
BRTD	**Mean**	**79**	**77**	**80.6**	**81**	**83.5**	**83.5**	**86**	**84.33**	**85.5**	**82**
	SD	**0**	**0**	**1.85**	**1**	**1.5**	**0.5**	**0**	**0.47**	**2.6**	**1.41**
BRTO	**Mean**	**80.5**	**78.5**	**88**	**87.5**	**84.5**	**81.5**	**89**	**88.33**	**88**	**86.25**
	SD	**0.5**	**0.5**	**0.63**	**1.5**	**1.5**	**2.5**	**1**	**0.47**	**1.22**	**1.09**
ΔBR	**Mean**	**1.5**	**1.5**	**7.4**	**6.5**	**1**	**-2**	**3**	**4**	**2.5**	**4.25**
	SD	**0.5**	**0.5**	**2.06**	**0.5**	**0**	**2**	**1**	**0**	**2.69**	**2.05**
LRTD	**Mean**	**75.5**	**74**	**76.5**	**77**	**77**	**76**	**78.5**	**77.67**	**78**	**78.25**
	SD	**1.5**	**0**	**2.71**	**0**	**0**	**1**	**0.5**	**0.47**	**1.41**	**0.83**
LRTO	**Mean**	**87.5**	**86.5**	**83.4**	**87**	**83.5**	**89**	**86.5**	**81.33**	**80.25**	**78**
	SD	**2.5**	**2.5**	**1.36**	**3**	**0.5**	**1**	**1.5**	**2.49**	**1.92**	**2.55**
ΔLR	**Mean**	**12**	**12.5**	**6.6**	**10**	**6.5**	**6.5**	**8**	**3.67**	**2.25**	**-0.25**
	SD	**4**	**0.5**	**3.26**	**3**	**0.5**	**0.5**	**1**	**2.62**	**3.27**	**3.11**

Above table shows the mean back ward/forward trunk lean at the time of touchdown (BFTD) and at the time of toe off (BFTO) angle were higher in success jumps than failed jumps. The second subject's trunk angle change was high in backward lean in success jumps than failed jumps. Among all jumpers the second subject had highest value of 7.4 in backward lean (ΔBF) than others. We can be attributed that the combination of backward and lateral lean may be differed from individual to individual. . According to Dapena (1980b)in the side view (backward trunk lean) the longitudinal axis of the trunk should be leaning backward about 15 degrees at the start of the takeoff phase and it should not go beyond the vertical at the end of the takeoff phase. The left/right trunk lean at the time of touchdown(LRTD) angle values were almost equal between success and failed jumps and at the time of toe off(LRTO)some subjects had higher values than failed jump and some subjects had lower values than failed jumps. Among all jumpers second and fourth subjects showed higher difference between success and failed jumps.

The results of this study showed that rithesh kumar, arunkumar and amaranth had higher lateral trunk lean than backward trunk lean but in case of harshith and gowtham had almost equal components of trunk lean i.e. backward and lateral lean. These results can be attributed that if the forward and lateral somersaulting angular momentum generated during the takeoff phase are reasonably large amounts and if the athlete succeeds in generating this angular momentum without leaning excessively forward and toward the bar (in the side and back views respectively), the somersault rotation over the bar should be good. According to Dapena (1980b) from back view (lateral trunk lean) the longitudinal axis of the trunk (i.e., the line going from the base of the neck to the midpoint between the hips) should be leaning about 15 degrees away from the bar at the start of the takeoff phase and it should not be tilting toward the bar more than 10 degrees beyond the vertical at the end of the takeoff phase.

The jumpers with particularly large amounts of forward tilt and small amount of lateral tilt will produce the body will be tilted with the hip of the lead leg lower than the hip of the takeoff leg. Conversely jumpers with large amounts of lateral tilt and small amounts of forward tilt will produce the body with the hip of the take off leg lower than the hip of the lead leg (this problem does not occur very often).
The sum of the forward and lateral somersaulting angular momentum components adds up to the required total (or "resultant") somersaulting angular momentum.. In general, athletes with more angular momentum will tend to rotate faster.

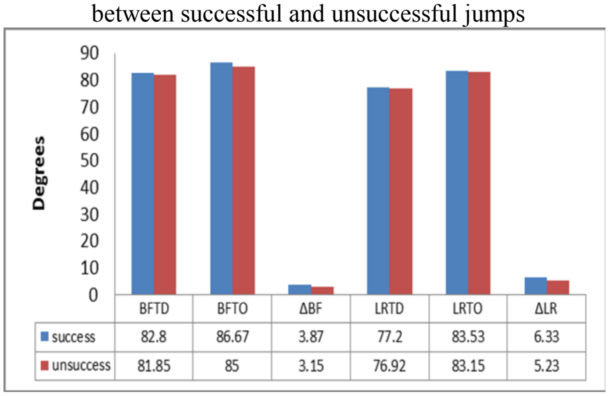
Table:- all subjects mean differences between success and unsuccessful jumps.

Variable		Success	Unsuccessful	t value
BFTD	MEAN	82.8	81.85	0.41
	SD	3.19	2.54	
BFTO	MEAN	86.67	85	0.21
	SD	2.91	3.76	
ΔBF	MEAN	3.87	3.15	0.56
	SD	3.18	2.96	
LRTD	MEAN	77.2	76.92	0.71
	SD	2.04	1.59	
LRTO	MEAN	83.53	83.15	0.81
	SD	2.99	4.82	
ΔLR	MEAN	6.33	5.23	0.56
	SD	4.22	5.26	

* Significant at 0.05 level (2.074)

The data indicates that the trunk lean of BFTD, BFTO, ΔBF, LRTD, LRTO, ΔLR was not significant difference between successful and unsuccessful jumps. The difference between means was not significantly differing at 0.05.

Figure 1. Comparison of trunk lean (backward and lateral) between successful and unsuccessful jumps



Summary and conclusions

This study indicates that all the five jumpers who have used the fosbury flop technique have shown insignificant differences on the variables tested. The deference in performance of the athletes can be attributed that the difference had shown in somersault rotation over the bar. The lower angle values of BFTD, ΔBF, LRTD and ΔLR produce at takeoff that generates a larger amount of vertical velocity and therefore a higher peak height for the centre of mass. We do not understand well the cause-effect mechanisms behind the statistical relationships and it is possible to offer alternative explanations such as the weaker athletes are not able to generate much lift mainly because they are weak. Therefore they are not able to jump very high. This makes them reach the peak of the jump relatively soon after takeoff. Consequently they will want to rotate faster in the air to reach a normal horizontal layout position at the peak of the jump. We cannot be sure of which interpretation is correct one does the trunk tilt affect the height of the jump or does the weakness of the athlete affect the height of the jump and (indirectly) the trunk tilt?
Through the literature we conclude that if the athlete wants to generate a good amount of lateral somersault angular momentum it will be necessary to have a good amount of lean away from the bar at the start of the takeoff phase. To achieve this curve of the run-up has to be tight enough (but it should not be so tight that the athlete has difficulty running fast) also the athlete should lean with whole body while running the curve.
If the athlete wants to generate a good amount of forward somersaulting angular momentum he will need to have a good amount of backward lean at the start of the takeoff phase. To achieve this trunk has to be perfectly vertical one step before takeoff. Then the athlete has to thrust the hips clearly forward in the final part of the last step of the run-up to produce a backward lean of the trunk at the start of the takeoff phase. During the takeoff phase the athlete needs to allow the trunk to rotate forward and reach the vertical at the end of the takeoff (in the view from the side).

RECOMMENDATIONS

These observations suggest that the athletes would be focused on other aspects like diagonal arm swing action which contributes more to the generation of lateral somersaulting angular momentum and interferes less with the generation of forward somersaulting angular momentum.
Every coach should check :
If an athlete is not leaning enough away from the bar at the start of the takeoff phase the coach should first check whether the athlete is leaning with the whole body or only with legs in the last steps of the run-up.
If only the legs are leaning the athlete has to learn how to lean with the whole body while running the curve. If that is not the problem it will be necessary to tighten the radius of the run-up curve.

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