International Journal of Yoga, Physiotherapy and Physical Education
ISSN: 2456-5067
Impact Factor: RJIF 5.24
www.sportsjournal.in
Volume 3; Issue 2; March 2018; Page No. 258-261

Kinematic analysis of barefoot and shod running in top speed zone of 100M sprints

Tapas Bapari[1], Dr. Nita Bandyopadhyay[2]
[1] Research Scholar, Department of Physical Education, University of Kalyani, Kalyani, West Bengal, India
[2] Assistant Professor, Department of Physical Education, University of Kalyani, Kalyani, West Bengal, India

Abstract
Purpose of the present study was to analyse the action of running with shoes and without shoes in respect of some selected kinematic parameters. Fifteen male athletes (sprinters) and fifteen male non-athletes were selected as subject. The selected kinematic parameters were (I) Stride Length (II) Stride Frequency (III) Horizontal Velocity (IV) Stride Time (V) Flight Time (VI) Contact Time (VII) Upper Body Inclination (VIII) Push Leg Inclination (IX) Swing Leg Knee Angle (X) Push Leg Knee Angle (XI) Front Arm Elbow Angle (XII) Back Arm Elbow Angle. The movement of running was recorded by a video camera and the parameters were analyzed by freeze frame technique. To findout the difference on selected kinematic parameter between with shoes and without shoes of athlete group and non-athlete the t-test was conducted and the significant level was set at $p<0.05$ level. Results revealed that there were statistically significant difference between running with shoes and without shoes in contact time and horizontal velocity for Athlete group but with shoes provide over all better performance for athlete group. For Non Athlete group no significant differences were found in selected parameters.

Keywords: running, barefoot, kinematic analysis

Introduction
Running is a method of terrestrial locomotion allowing humans and other animals to move rapidly on foot. Running is a type of gait characterized by an aerial phase in which all feet are above the ground. The term running can refer to any of a variety of speeds ranging from jogging to sprinting. Jogging is running slowly and sprinting is running fast. It is assumed that the ancestors of mankind developed the ability to run for long distance about 2.6 million years ago, probably in order to hunt animals. (Discover Magazine, 2006) [1]. Once upon a time players of all games and sports ran barefoot. Throughout most of human history, running was performed while barefoot or in thin-soled shoes such as moccasins. Historians believe that the runners of Ancient Greece ran barefoot. After some time technology has been developed in all fields. Like all other fields technology has developed in sports and games and from that time players of most of the games and sports run with different shoes. Present study was to analyze the responsible mechanical factors for performance of running.

Methodology
Fifteen male athletes (sprinters) and fifteen male non-athletes were selected as subjects for the present study. Athletes participated in State level athletic meet and University Athletic meet. The selected mechanical parameters were (I) Stride Length (II) Stride Frequency (III) Horizontal Velocity (IV) Stride Time (V) Flight Time (VI) Contact Time (VII) Upper Body Inclination (VIII) Push Leg Inclination (IX) Swing Leg Knee Angle (X) Push Leg Knee Angle (XI) Front Arm Elbow Angle (XII) Back Arm Elbow Angle. 50 m to 55 m was considered as top speed zone in 100 m distance. Top speed zone was marked on the ground by lime dust and cone.

In the beginning of recording of movement of running the purpose of recording was briefly explained to all the subjects for better understanding and to increase motivation level. In top speed zone the movement of running of the subject was recorded by a video camera manufactured by Sony company following the basic principle of photography.

a. The recording of movement was done by using fixed camera. The camera was made by Sony Company and the camera frequency was 24 frame/Sec.
b. The axis of the camera was perpendicular to the direction of movement of running to be recorded.
c. The lateral distance of the camera was 11 meter and the height of the camera was 1 meter from the ground.

The top speed zone was marked on the ground in 100m distance by lime dust and cone. According to Gundha (1969) found that in track and field sprint it can last from 20 m to 45 m. So in the present study 50 m to 55 m was considered as top speed Zone.
Placement of camera for recording running movement has been shown in figure-1

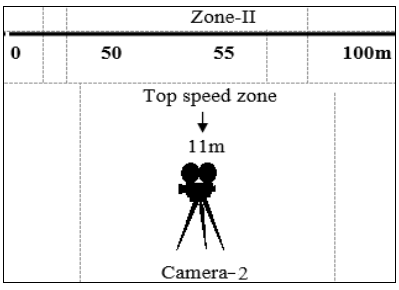

Fig 1

To measure the selected kinematics parameters the film was analyzed. The capture movement was transferred from the camera to the computer and CD was made for the purpose of analysis. Then the recorded movement of running was displayed by computer and the movement of each subject was analyzed with the help of appropriate software. After projecting a particular frame, the stickman configuration was drawn from the frame. For measurement of angle at different joints the line was drawn on the screen on a transparent sheet to indicate the required limb position for each subject and each movement. To avoid much overlapping a new transparent sheet was needed for every new subject frame. The time information was obtained from the frequency of the camera. In the process the different selected kinematic parameters were measured.

Results

Table 1: Testing significance of difference between mean values in selected kinematic parameters for running with shoes and without shoes for Athlete group in top speed zone of 100m running

Parameter	Condition of running	Mean Value	S.D	Mean Difference	DF	T.Value	Remarks
Stride Length (cm)	Running With Shoe	2.71	0.181	0.07	28	1.061	Not Significant
	Running Without Shoe	2.64	0.180				
Stride Frequency (no/Sec)	Running With Shoe	4.33	0.223	0.09	28	1.125	Not Significant
	Running Without Shoe	4.24	0.237				
Horizontal Velocity (cm/Sec)	Running With Shoe	11.70	0.572	0.54	28	2.365	Significant
	Running Without Shoe	11.16	0.691				
Stride Time (Sec)	Running With Shoe	0.23	0.012	0.01	28	1.103	Not Significant
	Running Without Shoe	0.24	0.014				
Flight Time (Sec)	Running With Shoe	0.11	0.011	0.00	28	0.768	Not Significant
	Running Without Shoe	0.11	0.007				
Contact Time (Sec)	Running With Shoe	0.12	0.008	0.01	28	2.165	Significant
	Running Without Shoe	0.13	0.012				
Upper Body Inclination (o^0)	Running With Shoe	79.83	4.483	1.20	28	0.906	Not Significant
	Running Without Shoe	81.03	2.489				
Push Leg Inclination (o^0)	Running With Shoe	48.40	2.465	0.80	28	1.142	Not Significant
	Running Without Shoe	49.20	1.131				
Swing Leg Knee Angle (o^0)	Running With Shoe	63.93	8.674	0.44	28	0.148	Not Significant
	Running Without Shoe	64.37	7.303				
Push Leg Knee Angle (o^0)	Running With Shoe	168.36	2.318	1.00	28	1.034	Not Significant
	Running Without Shoe	167.36	2.943				
Font Arm Elbow Angle (o^0)	Running With Shoe	71.33	13.189	3.34	28	0.754	Not Significant
	Running Without Shoe	74.67	10.929				
Back Arm Elbow Angle (o^0)	Running With Shoe	121.73	16.670	1.87	28	0.355	Not Significant
	Running Without Shoe	123.60	11.700				

The value of 't' $p<0.05=2.05$ at df =28

It is seen from the table that running with shoes and without shoes does not show any significant difference in Stride Length, Stride Frequency, Stride time, Fright time, Upper body inclination Push leg inclination, Swing leg knee angle, Push leg knee angle, Font arm elbow angle and Back arm elbow angle. But running with shoes shows statistically significant higher values for Horizontal velocity and significantly lower value for contact time which may be considered as prerequisite.

Table 2: Testing significance of difference between mean values in selected kinematic parameters for running with shoes and without shoes for non-athlete group in acceleration phase of 100m sprint

Parameter	Condition of running	Mean Value	S.D	Mean Difference	DF	T.Value	Remarks
Stride Length (cm)	Running With Shoe	2.49	0.203	0.09	28	1.359	Not Significant
	Running Without Shoe	2.40	0.173				
Stride Frequency (no/Sec)	Running With Shoe	3.84	0.328	0.18	28	1.540	Not Significant
	Running Without Shoe	4.02	0.307				
Horizontal Velocity (cm/Sec)	Running With Shoe	9.54	0.775	0.08	28	0.286	Not Significant
	Running Without Shoe	9.62	0.806				
Stride Time (Sec)	Running With Shoe	0.26	0.022	0.01	28	1.585	Not Significant
	Running Without Shoe	0.25	0.014				
Flight Time (Sec)	Running With Shoe	0.12	0.015	0.00	28	1.282	Not Significant
	Running Without Shoe	0.12	0.011				
Contact Time (Sec)	Running With Shoe	0.14	0.016	0.01	28	0.963	Not Significant
	Running Without Shoe	0.13	0.017				

Upper Body Inclination (o^0)	Running With Shoe	80.90	5.458	1.33	28	0.731	Not Significant
	Running Without Shoe	82.23	4.480				
Push Leg Inclination (o^0)	Running With Shoe	50.17	3.092	1.47	28	1.405	Not Significant
	Running Without Shoe	48.70	2.604				
Swing Leg Knee Angle (o^0)	Running With Shoe	68.13	9.442	5.07		1.360	Not Significant
	Running Without Shoe	73.20	10.910				
Push Leg Knee Angle (o^0)	Running With Shoe	164.90	4.273	0.37		0.234	Not Significant
	Running Without Shoe	164.53	4.307				
Font Arm Elbow Angle (o^0)	Running With Shoe	88.43	11.982	4.20	28	0.891	Not Significant
	Running Without Shoe	84.23	13.781				
Back Arm Elbow Angle (o^0)	Running With Shoe	124.93	14.719	2.36	28	0.396	Not Significant
	Running Without Shoe	122.57	17.840				

The value of 't' $p<0.05=2.05$ at df =28

From the above table it appears that these were no significant difference on Stride Length, stride frequency, Horizontal velocity, stride time, Flight time, Contact time, Upper body inclination, Push leg inclination, Font arm elbow angle and Back arm elbow angle.

From statistical analysis of data following results were obtained.

1. For trained athlete (sprinter) running with shoes provided statistically significant better result for horizontal velocity, contact time which helped the athlete to perform better in top speed zone of 100m sprint.
2. For non-athlete with shoes and without shoes group, none of these results was statistically significant in top speed zone of 100m sprint.

Discussion

In the present study it has been observed that the athlete group with shoes and without shoes showed no significant difference in Stride Length, Stride Frequency, Stride Time, Flight Time, Upper Body Inclination, Push Leg Inclination, Swing Leg Knee Angle, Push Leg Knee Angle, Front Arm Elbow Angle, Back Arm Elbow Angle in top speed zone of 100m sprint and for non-athlete group also there was no significant difference in Stride Length, Stride Frequency, Stride Time, Flight Time, Contact Time, Upper Body Inclination, Push Leg Inclination, Swing Leg Knee Angle, Push Leg Knee Angle, Front Arm Elbow Angle, Back Arm Elbow Angle in top speed zone of 100m sprint. That means from the present study it may be concluded that running shoe or spike has no impact on Stride Length, Stride Frequency, Stride Time, Flight Time, Upper Body Inclination, Push Leg Inclination, Front Arm Elbow Angle, Back Arm Elbow Angle in top speed zone of 100m sprint.

Horizontal Velocity

In the present study it has been observed that there was significant difference in Horizontal Velocity between the Athlete with shoes and barefoot runners in top speed zone but in case of non-athlete group no significant difference has been observed between with shoes and barefoot runners. In the present study it may be concluded that the running shoe has significant impact on horizontal velocity.

Smith *et al* (2014) [9] compared the barefoot and sprint spike shod foot condition and concluded that sprint spikes significantly increase sprinting velocity. The results of the present study in close proximity with other leading researcher.

Contact Time

In Contact Time it has been observed that there was significant difference between the Athlete with shoes and barefoot runners in top speed zone but in case of non-athlete group no significant difference has been observed between with shoes and barefoot runners. In the present study it may be concluded that the running shoe has significant impact on Contact Time.

Nummela *et al*. (2007) [7] investigated the relationships between running mechanics, top running speed and economy in young endurance athletes. They suggested that ground contact time was the only factor which correlated significantly with both running economy ($r = 0.49$, $p < 0.05$) and maximal running speed and short contact times required in economical and high speed running.

Kong *et al.* (2008) [4] observed that the short ground contact time was related to good running economy since there is less time for the braking force to decelerate forward motion of the body.

Hasegawa *et al.* (2007) [2] observed that a shorter contact time and a higher frequency of inversion at the foot contact might contribute to higher running economy. So the results of the present study is in close proximity with other the leading researcher.

Conclusion

On the basis of results obtained from statistical analysis of data, following conclusions were drawn:

1. For trained athlete running with shoes may facilitates in performing better than running without shoes in top speed zone of 100m sprint.
2. 2. Running with shoes may not provide any advantage in performance for untrained athletes in top speed zone of 100m sprint.

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