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Kinematic analysis of barefoot and shod running in acceleration phase of 100M sprints

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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. 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. Fifteen male athletes (sprinters) and fifteen male non-athletes were selected as subject. The movement of running was recorded by a video camera and the parameters were analyzed be freeze frame technique. Results revealed that there were statistically significant difference between running with shoe and without shoe contact time, horizontal velocity and knee angle of swing leg for Athlete group. In all the cases running with shoe provides better performance. For Non Athlete group statistically significant difference appears only in Knee Angle of Push Leg. With shoe even the Non Athlete can push the ground with higher angle. Without shoe the subjects bend the push leg more at knee, which is bad for running performance. For other selected parameters there appears no significant difference.

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.

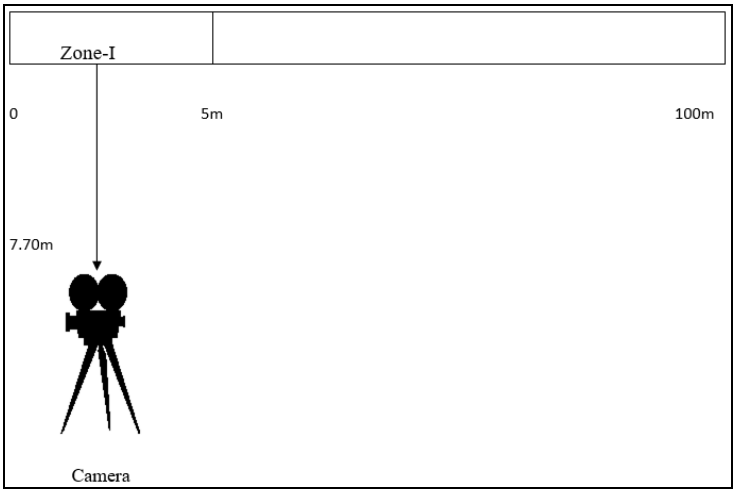
Present study was to analyze the responsible mechanical factors for performance of running.

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. 1 m to 5 m was considered as acceleration phase (zone) in 100 m distance. Acceleration phase (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 acceleration 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.
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 7.70 meter and the height of the camera was 1 meter from the ground.

The acceleration phase (zone) was marked on the ground in 100m distance by lime dust and cone. According to Singh (1991) in the 1st second 55% increase in speed can be made. So in the present study 1m to 5m was considered as acceleration phase (zone) or starting Zone (zone-1)
Placement of camera for recording running movement has been shown in figure-1

Acceleration
Phase (zone)



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 acceleration phase of 100m running

Parameter	Condition of running	Mean Value	S.D	Mean Difference	DF	T. Value	Remarks
Stride Length (cm)	Running with Shoe	1.23	+ 0.077	0.04	28	1.183	Not significant
	Running without shoe	1.19	+ 0.095				
Stride Frequency (no/sec)	Running with Shoe	3.46	+ 0.173	0.04	28	0.564	Not significant
	Running without shoe	3.42	+ 0.208				
Horizontal Velocity (Cm/sec)	Running with Shoe	4.25	+ 0.194	0.18	28	2.801	significant
	Running without shoe	4.07	+ 0.163				
Stride Time (Sec)	Running with Shoe	0.29	+ 0.014	0.00	28	0.663	Not significant
	Running without shoe	0.29	+ 0.018				
Flight Time (Sec)	Running with Shoe	0.08	+ 0.012	0.01	28	1.998	Not significant
	Running without shoe	0.07	+ 0.010				
Contact Time (Sec)	Running with Shoe	0.21	+ 0.014	0.02	28	2.229	significant
	Running without shoe	0.23	+ 0.015				
Upper Body Inclination (0º)	Running with Shoe	36.55	+ 3.940	0.48	28	0.310	Not significant
	Running without shoe	37.03	+ 4.566				
Push Leg Inclination (0º)	Running with Shoe	51.90	+ 1.550	0.05	28	0.078	Not significant
	Running without shoe	51.95	+ 1.942				
Swing Leg Knee Angle (0º)	Running with Shoe	98.97	+ 3.862	5.23	28	3.257	significant
	Running without shoe	104.20	+ 4.880				
Push Leg Knee Angle (0º)	Running with Shoe	171.06	+ 2.517	0.75	28	0.764	Not significant
	Running without shoe	170.31	+ 2.850				
Font Arm Elbow angle (0º)	Running with Shoe	67.70	+ 15.339	0.45	28	0.089	Not significant
	Running without shoe	67.25	+ 12.321				
Back Arm Elbow angle (0º)	Running with Shoe	132.22	+ 9.90	2.35	28	0.089	Not significant
	Running without shoe	129.87	+ 10.60				

It is seen from the table that, though not statistically significant, the condition of running with shoes provided better results in stride length, stride frequency, stride time, flight time, upper body inclination, push leg inclination, swing leg knee angle, push leg knee angle and front arm elbow angle. Of course, running with shoes provides statistically significant higher values for horizontal velocity. Contact time was also appeared to be significantly lower for running with shoes, which is a better condition for gaining higher velocity. Swing leg angle was also found to be more favorable for running with shoes in statistically significant level.

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 running.

Parameter	Condition of running	Mean Value	S.D	Mean Difference	DF	T Value	Remarks
Stride Length (cm)	Running with Shoe	1.19	+ 0.070	0.03	28	1.362	Not significant
	Running without shoe	1.16	+ 0.050				
Stride Frequency (no/sec)	Running with Shoe	2.98	+ 0.220	0.10	28	1.269	Not significant
	Running without shoe	3.08	+ 0.201				
Horizontal Velocity (Cm/sec)	Running with Shoe	3.55	+ 0.207	0.00	28	0.027	Not significant
	Running without shoe	3.55	+ 0.226				
Stride Time (Sec)	Running with Shoe	0.34	+ 0.023	0.01	28	1.401	Not significant
	Running without shoe	0.33	+ 0.020				
Flight Time (Sec)	Running with Shoe	0.07	+ 0.013	0.01	28	1.407	Not significant
	Running without shoe	0.06	+ 0.010				
Contact Time (Sec)	Running with Shoe	0.27	+ 0.025	0.00	28	0.572	Not significant
	Running without shoe	0.27	+ 0.022				
Upper Body Inclination (0^o)	Running with Shoe	42.65	+ 4.732	1.35	28	0.782	Not significant
	Running without shoe	41.30	+ 4.729				
Push Leg Inclination (0^o)	Running with Shoe	55.30	+ 2.698	0.92	28	1.030	Not significant
	Running without shoe	54.38	+ 2.144				
Swing Leg Knee Angle (0^o)	Running with Shoe	106.58	+ 5.920	0.97	28	0.392	Not significant
	Running without shoe	107.55	+ 7.504				
Push Leg Knee Angle (0^o)	Running with Shoe	159.28	+ 2.884	3.18	28	2.834	significant
	Running without shoe	162.46	+ 3.257				
Font Arm Elbow angle (0^o)	Running with Shoe	84.50	+ 17.675	1.00	28	0.167	Not significant
	Running without shoe	85.50	+ 15.023				
Back Arm Elbow angle (0^o)	Running with Shoe	126.95	+ 9.857	0.38	28	0.109	Not significant
	Running without shoe	127.33	+ 9.358				

From the above table it appears that for non-athlete group, the condition of running without shoes provided better results in stride frequency, horizontal velocity, stride time, contact time, upper body inclination and push leg inclination. Of course, none of these better results was statistically significant. The only statistically significant difference resulted in push leg knee angle and the condition of running without shoes provided better results here.

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 and swing leg knee angle which helped the athlete to perform better in acceleration phase of 100m sprint.
2. For non-athlete barefoot runner group, statistically significant results were obtained in push leg knee angle but it does not affect the performance in any manner in acceleration phase 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 acceleration phase of 100m sprint and for non-athlete group also there was 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 acceleration phase 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 acceleration phase 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 acceleration phase 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 in achieving quick acceleration.

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 acceleration phase 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.

Swing Leg Knee Angle

In athlete group there was significant difference in Swing Leg Knee Angle in acceleration phase that means in case of athlete group the barefoot runners showed greater Swing Leg Knee Angle in acceleration phase. That may be due to unused in practice without shoes. For non-athlete group there was no significant difference in Swing Leg Knee Angle between with shoes and without shoes in acceleration phase. That means from the present study it may be concluded that running shoe or spike has no impact on Swing Leg Knee Angle.

Push Leg Knee Angle

In the present study it has been observed that the athlete group with shoes and without shoes showed no significant difference in Push Leg Knee Angle in Acceleration phase and for non-athlete group there was significant difference in acceleration phase that means in case of non-athlete group the barefoot runners showed significantly greater Push Leg Knee Angle in acceleration phase though it had not affect the performance in acceleration phase but the results obtained as because they were used to run barefoot. From the present study it may be concluded that running shoe or spike has no impact on Push Leg Knee Angle.

Conclusion

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

1. Running with shoes provides better condition for performance for trained athletes in acceleration phase of 100m sprint.
2. Running with shoes does not provide better condition for performance for untrained athletes in acceleration phase of 100m sprint.

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