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EFFECT OF THREE REAR BLOCK PEDAL-ANGLES ON THE KINEMATIC PATTERNS OF SPRINT-START PERFORMANCE

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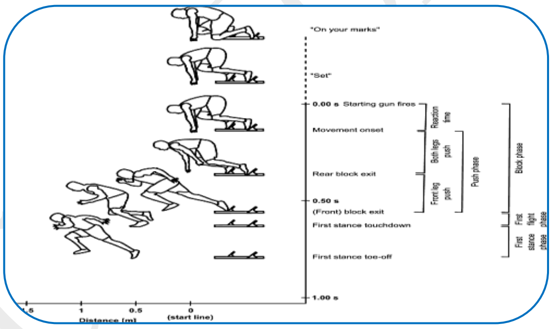
ABSTRACT :

Athletes have a considerable freedom in choosing the configuration of the starting block. This study intended to understand how the changes in block angles of the rear block affected the kinematics of the athletes leaving the blocks. Five highly experienced athletes, all of which had previous success in the national level events were chosen as subjects for this study. The video graphic method was used in this study to unveil the 2-D kinematics of the sprinters. The study found an inverse relation with the block pedal angles and the angular velocity of the ankle joint of the sprinters.



KEYWORDS : *kinematics, block pedal angles and angular velocity.*

INTRODUCTION

Sprint distances at Olympic events include 100m, 200m and also the 400m, with competitors constantly seeking individual improvement. It is common to see winning margins of less than 0.01s in many of these sprint events; therefore small alterations in performance can be the defining factor between gold and silver medal placings (Docherty and Hodgson, 2007; Young, 2006).

In the set position, athletes can increase the joint moment of their lower limbs to their advantage by changing the block obliquity of the starting blocks to an adjustment that is most suitable to them (e.g. Mero, Luhtanen, &Komi, 1983; Dickinson, 1934).It is potentially because an athlete achieves a muscle-tendon length that prolongs the block clearance phase to achieve more power output by increasing muscle activity.

The block obliquity or inclination has also been a focus of study on many occasions. In their papers that go around block obliquity Guissard (1992) chose 70^0,50^0 and 30^0 for the front block while keeping rear block constant at 70^0 angle, while Mero et al.(2007) chose 40^0 and 65^0 to study the effect of block angle at both feet.

No effort has been made so far by any author to study exclusively the effect of various block (rear) angles to the start performance of an athlete. Moreover, athletes have a considerably more variations to choose from. Until now no research has been published on rear block angles of 40^0,50^0 or 60^0 using highly skilled participants with focus on kinematics.

Though Salo et al. (2108) published very recently on rear block angles of 40^0,50^0& 60^0however; their study was confined to the kinetics of the start while the kinematics of the start remains untouched.

How the change in block angles changes the kinematics from the start to first stride is still unknown? The role of the sprinter's body configuration at touchdown also remains unclear (Bezodis et al., 2019).

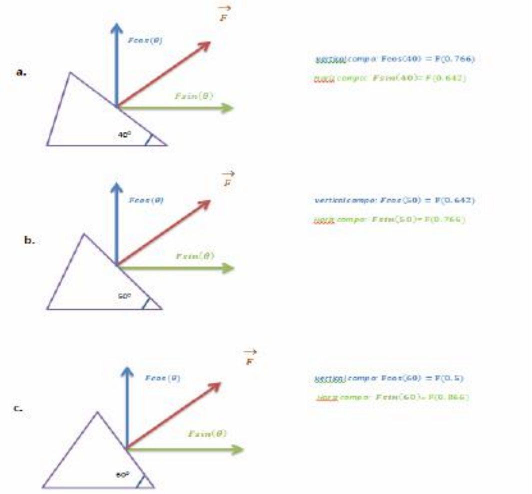


Figure 1:shows the vector resolution of Force applied by the athlete on the block-pedal and the variation caused by the change in block-pedal angle

When the athlete pushes against the block pedal the force that the athlete puts on the pedal is reciprocated with the equal amount in the direction normal to the plane of the pedal. The depiction in the previous page show the two components of the force vector $\vec{F}$ at three different block pedal angles. Mathematically, as the block pedal increases the vertical component of the force vector decreases, while the horizontal component increases.

METHOD

PARTICIPANTS

Five participants (M±S.D; Age 26.8±1.92, height (cm) 171.2±5.16, body mass (kg) 65.4±2.73 and training experience (years) 7.6±2.07), who had previous success in the national events in sprint were chosen as participants in this study.

Table 1: Anthropometric data of sprinters

Name	Age(years)	Height(cm)	Body mass(kg)	Leg length(cm)	Training experience(years)	Medals won at national level in sprint events
A. Ravi Kumar	26	168	57	38+42=80	6	One gold medal
B. MukeshPathak	30	165	67	40+37=77	11	One gold medal & Three silver medals
C. Arshdeep Singh	25	170	64	41+38=79	6	One gold medal & three silver medals
D. Hitesh Deshwal	27	176	74	45+42=87	7	One gold medal, two silver medals and one bronze medals
E. Yuvraj Singh	26	177	65	45+49=94	8	One gold medal

FILMING PROTOCOL

Motion analysis method was used in this study to record the data on the athletes. A video camera (CASIO EX-FH) that recorded at the speed of 50 frames per second was used. The camera was put perpendicular to the plane (sagittal plane) of motion at a distance of 7 meters so that it could capture the athlete in set position as well as the few successive steps taken by the athlete. The camera was put on a tripod to keep the camera stationary at a height of 0.8 meters. The camera was used with 1.0 zoom to record the data in HD (1080 pixels). The camera was set-up such that the field of view of the camera would record the sprinter in the "set" position and the three successive steps that they would take.The camera was used with 1.0 zoom to record the data in HD (1080 pixels). The camera was set-up such that the field of view of the camera would record the sprinter in the "set" position and the three successive steps that they would take.

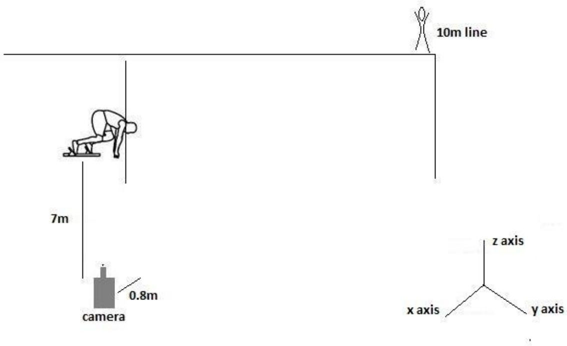


Figure 3.1: Plan view of the data collection set-up

Testing conditions

Testing took place in the beginning of the summer session on a tartan track in the outdoor setting on the Track A. of National institute of sports, Patiala. After a personalized warming up which consisted of jogging fallowed by stretching exercises the athletes took a test run. After that was done, the athletes ran four to six maximal-effort 20m runs, with complete recovery of the athlete between the sprints. The subjects wore their own spikes and stretchable shorts during the test which they use in competitions. Starting command was identical to that what is used in a competition setting.

The sprinters were asked to set-up the start-block for themselves as they do in the competition setting which varied for each athlete in the block spacing, distance from the starting line as well as in the block obliquity. After the athletes had set-up their blocks each sprinters did their test run to test the block conformity. For their next runs the research scholar intervened by changing the block-obliquity of the blocks while no other tampering was done to start-blocks. For their First run the rear block obliquity was "set" at 40^0 and was then increased to 50^0 and 60^0 block angles, while the front block angle was kept constant at 40^0 block angle. Each sprinter ran four to six Maximal-efforts 20m runs with enough time in between the runs so that the sprinters would get enough time for recovery. To serve this purpose the sprint start runs were randomized between the sprinters.

Apart from the research scholar eight other experienced sprinters who had a diploma in athletics coaching were also employed who worked as officials. Four of them were timekeepers, with two at 10m line and two at 20m line to keep the time independently.

One official was given the task to judge at the starting line while one more official held the clapper and positioned himself behind the start-blocks were the sprinters would place themselves.

Two more official remained seated on the sidelines and registered the information sent to them.

Criterion measure

To measure the performance of the athlete for the sprint start, a stopwatch was used to record the timing of the athletes at 10 m distance. Two testers independently recorded the timing at 10 m distance, this was done to increase the reliability of the data recorded.

Kinematic variables

i. Angle of the hip, knee and ankle joints in the "set" position.
ii. Angle of the hip, knee and ankle joints at the First contact (FC).
iii. Angular velocity of the hip joint at the time of block clearance (BC).
iv. Angular velocity of the knee joint at the time of block clearance (BC).
v. Angular velocity of the ankle joint at the time of the block clearance (BC).

Statistical analysis

The conventional statistical methods were used to calculate the value of means, standard deviation and Pearson's correlation coefficient. SPSS was used to calculate Analysis of variance (ANOVA) to compare the effects of the various block angle conditions on the measured kinematic variables. The statistical significance was set at $p<0.05$.LSD (least significant difference) test was used to check the post hoc results of the groups.

Landmarks used for location of white tape makers

The athletes were marked with white tape markers with dimensions of 3*3 cm which were placed at various anatomical landmarks that are as follows:

1. METATARSAL PHALANGEAL JOINT
2. HEEL
3. LATERAL MALLEOLUS
4. LATERAL EPICONDYLE OF HUMERUS
5. EPICONDILE OF FEMUR

Determining the lower extremity muscle-tendon length during flexion/extension movements

Hawkins and Hull (1992) developed a regression equation which was used to determine the length of three lower extremity muscles that are as:

1. Vastusmedialis
2. Solius
3. Medial gastrocenimus

The equation developed by Hawkins reads as follows:

$$L = C0 + C1x + C2\beta + C3\beta^2 + C4\phi$$

Were C0-C4 are the regressions equations constant and α, β & ϕ are the flexion angles of the hip, knee and ankle joints.

The equation determines the length of the muscle-tendon unit as a function of the lower limb joint configuration. The joint angles were known using the computer software (silicon coach pro ver-8) and were put in the equation to give out the normalized muscle length at three different block inclination (40^0, 50^0& 60^0) for all the five athletes. The normalized muscle length was then converted into meters by multiplying the values by the corresponding segment length. The correlation coefficients for the Vastus-medialis, Soleus and Medial gastrocnemius were 0.91, 0.82 & 0.97 respectively.

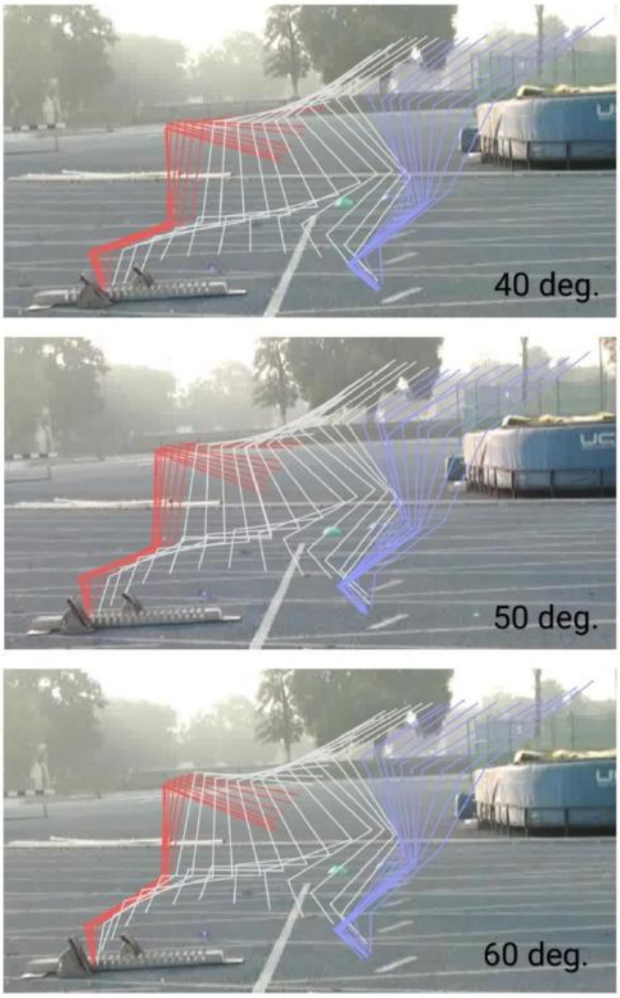


Figure 3:Stick figure analysis of sub. D at various block angels (Block phase, flight phaseandfirst support phase)

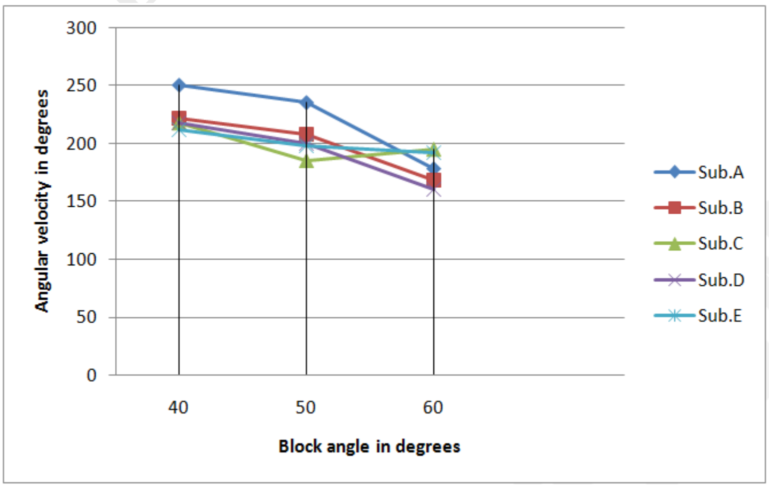


Figure 5: Angular velocity of the ankle joint at the time of block clearance (BC)

The graph shows the angular velocity (degrees) of ankle joint (AVOAJ) of the sprinters at various block obliquity angles found by this study. Of all the lower extremity joints (hip, knee and ankle) the change in the block obliquity had a dramatic effect on the angular velocity of the ankle joint of all the sprinters. All the five sprinters showed a decrease in the angular velocity when the block obliquity increased, except for the subject C who had a decrease (33 degrees) in AVOAJ when going from 40^0 block angle to 50^0 block angle though an increase (10 degree) when going from 50^0 block angle to 60^0 block angle. According to the authors understanding the possible reason behind this could be that the sprinter (sub. C) was used to this amount of block obliquity which resulted in a greater AVOAJ at the 60^0 block angle.

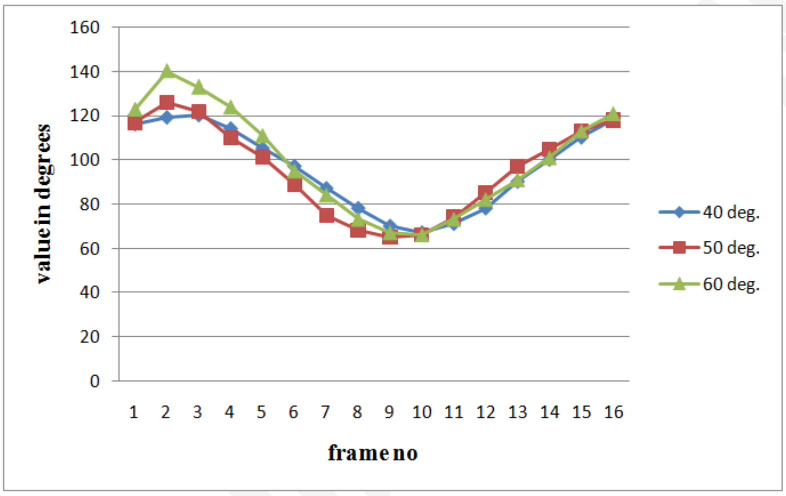
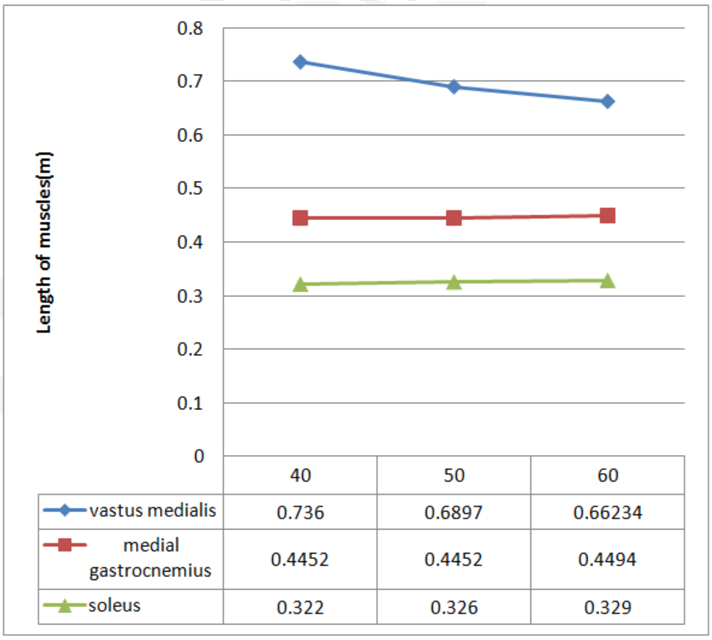


Figure 6: shows the effect of various block obliquity angles on the knee joint angle from "set" to first contact (Subject A)



	40	50	60
vastus medialis	0.736	0.6897	0.66234
medial gastrocnemius	0.4452	0.4452	0.4494
soleus	0.322	0.326	0.329

Figure 7: Change in the muscle-tendon length at various block obliquities of sub. A

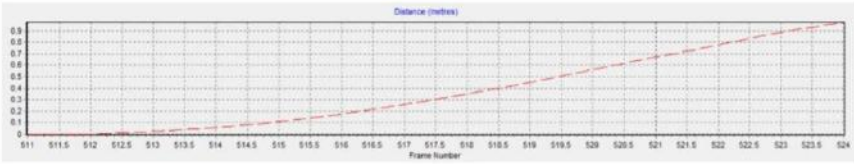
The Graph 4.6 displays the results which were calculated using Hawkin and Hull (1992) equation. The graph displays the length (m) of three muscles (vastusmedialis, medial gastrocnemius and soleus) at three block obliquities (40^0,50^0 and 60^0)for subject A.

For the vastusmedialis group of muscles the length decreased from 0.736m to 0.689m to 0.662m when the block obliquity increased from 40^0 to 50^0 and 60^0.

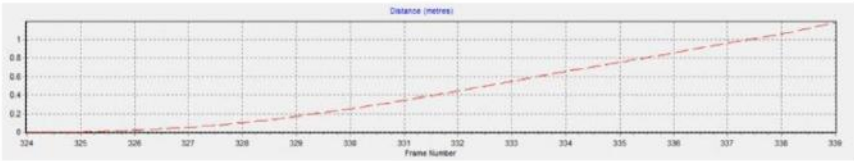
For the medial gastrocnemius muscle group there was hardly any change recorded with muscle length remaining more or less same.

The soleus muscle saw a gentle rise in the length from 0.322m to 0.326 to 0.329 when the block obliquity increased from $40^0$to 50^0 and 60^0.

At 40^0 block angle



At 50^0 block angle



At 60^0 block angle

Figure 8. Displays the distance time graph of the sprinter(c) at various block obliquities

RESULTS

The figure 8 shows that as the block obliquity increases from the distance covered by the sprinter also increases from 0.9m to 1.9m to 1.2m at 40^0, 50^0 and 60^0 block obliquity respectively.

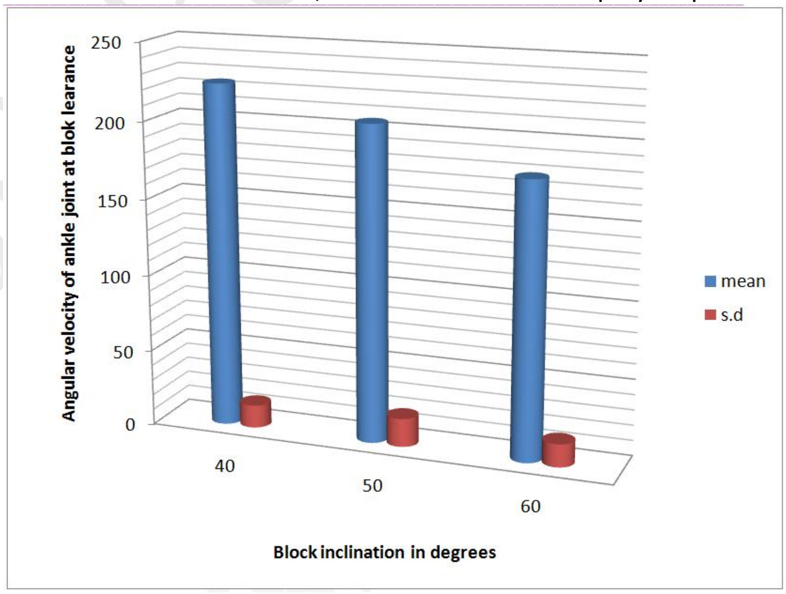


Figure 9: shows the effect of block angle variation (40^0,50^0 and 60^0) on the angular velocity of the ankle joint of the sprinters.

Table 2.One way ANNOVA angular velocity of ankle joint at various block obliquities.

SOURCE OF VARIANCE	SUM OF SQUARES	DF	MEAN SQUARE	F-RATIO	SIG.
BETWEEN GROUPS	5203.60	2	2601.8	9.8	0.003
WITHIN GROUPS	3186.0	12	265.5		
TOTAL	8389.60	14			

Table 2 displays the results of ANOVA statistical test of angular velocity of the ankle joint at three block obliquities 40^0,50^0 and 60^0.

Table 3:Post Hoc analysis of angular velocity of ankle joint at various block obliquities

I(group)	J (group)	MEAN DIFFERENCE(I-J)	Std. Error	SIG.
40^0 block angle	50^0 block angle	18.8	10.3054	0.093
	60^0 block angle	45.4*	10.3054	0.001
50^0 block angle	40^0 block angle	-18.8	10.3054	0.093
	60^0 block angle	26.6*	10.3054	0.024
60^0 block angle	40^0 block angle	-45.4*	10.3054	0.001
	50^0 block angle	-26.6*	10.3054	0.024

*The mean difference is significant at the 0.05 level

The table 4.1.2 displays the results from LSD test (least significant difference test) for post-hoc analysis. There was a mean difference of 45.4 between 40^0 and 60^0 block angle which was significant at 0.05 level of significance. A mean difference of 26.6 existed between 50^0 and 60^0 block angles which was also significant at 0.05 level of significance. A mean difference value of 18.8 was calculated by the post-hoc test between 40^0 and 50^0 block angles which was not significant at 0.05 level of significance.

DISCUSSION OF FINDINGS

1. There was a significant decrease in the ankle joint angular velocity when going from 40^0 to 60^0 and 50^0 to 60^0 block angle. The possible reason is that the block inclination increase the ankle joint in the "set" position becomes more extended, contrary to lower block angles which give the ankle joint more room to extend and thus contribute in the propulsion phase with greater velocity. As the block angles increase from 40,50 and 60, there was a decrease in the angular velocity (ϴ /s) at ankle joint (M±SD) 224±14.96, 205.2±18.59 and 178.6±15.05 respectively. Bauman (1976) pointed out that an efficient start depends on the extensors of hip and knee, including the ankle. The results on the five elite athletes indicated that their reduction in the extension of the hip and knee as the block inclination increased, though not significant statistically. However, the angular kinematics data of the ankle joint indicated a significant reduction in the extension of the ankle joint. This study suggests that the lower block angle gives more space for extension of lower limbs in the blocks and thus improving the start performance of an athlete.

This study resonated with the results of Guissard,N , Duchateaum, J and Hainaut ,C (1992). who investigated the electromyographic activity of three different muscles namely medial gastrocnemius , the soleus and the vastusmedialis during the sprint start on three different inclination angles(30^0,$50^0$and 70^0). The study suggests that a significant inverse relation existed as the block inclination angle changes from 70^0 to 50^0 and 30^0 with the start velocity without any significant change to the total pushing phase at the block and overall EMG activity. The increase in the velocity was attributed to neural and mechanical modifications. Mero et al., (2007) chose two block angles 40^0 and 65^0 for his study found that the muscle-tendon length was greater at 40^0 in both the legs which resulted in increased peak power output in both the ankles and increased power at the rear ankle.

2. Reducing the front block angle was shown to increase the take-off velocity from the blocks in the sprint start (Gaussard et al., 1992) and it was attributed to a more effective length-tension relation of the triceps surae muscle. Mero et al. (2007) examined this effect in both the blocks (front and rear) and asserted that the muscle-tendon lengths of the gastrocnemius and soleus of both the legs were greater at the 40^0 block angle. This study also examined the muscle-tendon lengths of three muscles (vastusmedialis, medial gastrocnemius and soleus) at the commonly used block angles for rear leg (40^0,50^0& 60^0). The vastusmedialis muscle decrease in size as the block obliquity increased while the opposite was true for soleus muscle which increased in size as the block obliquity increased. The medial gastrocnemius muscle showed no change. This study also concluded that the changes in the performance was because of the changes in the lower extremity muscle-tendon length especially vastusmedialis.

CONCLUSION

For the rear block it's suggested that the elite athletes should use the 40^0 block angle as this block angles contributes greatly to the angular velocity at the ankle joint and thus may contribute by greater margin with the production of propulsive forces during the block phase of the sprint-start.

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