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Kinematic Analysis of Arm Movements in 3000m Running: Before and After a Conditioning Programme

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ABSTRACT The present study was conducted on 50 adult males aged between 18-24 years to see the effect of a 90 days conditioning programme on their shoulder swing time during different laps of 3000 meter running and on performance time of 3000m run. A video film in the sagittal plane of right side of the body of the subject while performing 3000m run distance was recorded with a sophisticated video movie camera (in built time device) operating at 60 frames per second. It was observed that the right and left shoulder swing time, ratio of right and left shoulder swing time during different laps of 3000m running are statistically significantly improved ($p<0.05$) and the performance time of 3000m run also significantly decreased. No significant F- statistic was given by the order of variables entered in multiple regression analysis during pre test, post test-1 and post test-2, but the left shoulder swing time in the 15th lap of 3000m run indicate its importance in performance time of 3000 m run. It is concluded that the conditioning programme has caused a process of self-optimization of biomechanical aspects of running style to develop such a movement patterns which act as a fine tuning device to improve 3000m running time.

INTRODUCTION

The changing scenario in the field of running performance due to the introduction of scientific training methods all over the world has led to the preparation of athletes who are conditioned to develop almost comparable physiological capabilities. Recent evidence related to middle distance running has indicated running economy as an important correlate of successful running performance among individuals having comparable values of maximal aerobic power (Daniel 1985). Williams and Cavanagh (1987) have identified a number of biomechanical variables that are significantly related to running economy indicating that running mechanics affect metabolic energy demand. Morgan et al. (1994) observed a decrease in aerobic demand of runners by optimizing their biomechanical variables by training. The results of their study clearly imply that biomechanical factors contribute significantly to the determination of running economy.

A number of investigators have already demonstrated the effect of a conditioning /or training programme on the physiological and morphological variables in middle and long distance running athletes (Lortie et al.1984). But there are very few studies related to a conditioning/ or training programme which considers biomechanical responses particularly on Indian athletes. Keeping in view the role of shoulder swing time influencing 3000 m distance running performance, the present study has therefore been planned to be executed on subjects undergoing a conditioning programme of three months duration to investigate the shoulder swing time responses and their effect on 3000 m run performance time.

MATERIAL AND METHOD

The present investigation is a part of a major investigation conducted during 1999 to 2000 on fifty adult male students of different courses studying at Indira Gandhi Institute of Physical Education and Sports Sciences, New Delhi were examined. The age of the subjects ranged between 18-24 years. They were physical active and free from any medical contraindications.

In order to have a stride time record of the subject's responses to conditioning programme, a video film in the sagittal plane of right side of the body of the subject while performing 3000m run distance (which consists of 15 laps of 200 meter each and for a selected distance) was recorded at IGIPESS outdoor track with a sophisticated video movie camera (Panasonic- with timing devices) operating at 60 frames per second. The video camera was fixed on a tripod stand so that the focal axis of the lens was perpendicular to the plane of motion, and the camera-subject distance was kept large enough to minimize perspective error. It is likely that kinematic changes can occur with conditioning, in the other planes also as yet the greatest proportion segmental motion during running occur in the sagittal plane, therefore, it is convincing to believe that adjustments would be most readily detected in this plane. Prior to filming, reference markers were placed on anatomical landmarks by palpation of the bony prominences of the respective shoulder, elbow, wrist, hip, knee and ankle joints. Subjects wore their own athletic shoes and shoe markers remained glued in position for the pre- and post conditioning measurements. The video film thus recorded was analyzed on a high quality playback unit (Video Cassette recorder, National) having single frame advance capabilities to record kinematic variables. The single frame advance feature of this play back unit (VCR) enabled the investigator to take frame-by-frame measurements.

Design of a Conditioning Programme

The conditioning programme lasted for 90 days comprised of two mesocycles, of 45 days each. The first mesocycle consisted of exercises targeted to improve static flexibility and cardio-respiratory endurance. The second mesocycle on the other hand was designed to include those exercises which could improve dynamic flexibility, muscular strength and endurance. Each mesocycle was further divided into two sub-phases that is phase-I (22days) and Phase-II (23 days). The exercise regimen was administrated in the morning to the subjects five days a week and the duration of each daily session was kept 45 minutes. All subjects were asked to adhere to (a) No consumption of alcoholic drinks, drugs, or any other stimulant prior to a conditioning programme, (b) To avoid strenuous physical activity for a minimum of 12 – hours prior to a conditioning programme, and (c) Daily attendance and commitment to the conditioning schedule, during the course of conditioning programme.

Testing Protocol

The selected kinematic, physical and biological variables were recorded at the following stages:

a) Pre– Test [PT] that is, before the start of a conditioning programme

b) Post- Test – 1 [PT-1] that is, after the completion of first mesocycle (45days)

c) Post- Test –2 [PT-2] that is, after the completion of second mesocycle (90days)

Data analysis, using SPSS-X software involved the computation of descriptive statistics (Mean± SD) to describe the physical characteristics of the subjects. A difference among different groups concerning kinematic variables was assessed by using a repeated-measure one-way analysis of variance (ANOVA). Post hoc comparisons were accomplished using Scheffe. A multiple regression analysis was also used to bring into light the importance of some kinematic variables influencing 3000 m running performance. The probability level accepted for statistical significance was set at $p<0.05$.

RESULTS

The mean age and height was 20.2±1.37 years and 169.17±5.24 cm. The mean value of body weight and total time taken for 3000m running after conditioning programme (Table 1) shows a trend of decrease.

Table 1: Descriptive statistics of subjects

Variables	*Pre- test*	*Post- test-1*	*Post- test-2*
Age(years)	20.2 ± 1.37	20.2 ± 1.37	20.2 ± 1.37
Body Weight (Kg)	62.31± 6.53	60.23± 6.75	61.27± 6.61
Height(cm)	169.17± 5.24	169.17± 5.24	169.17± 5.24
Total Time Taken (seconds)	812.96±77.84	780.28±65.97	746.55±69.48

Right Shoulder Swing Time

The mean different right shoulder swing time during 3000m run before, after post- test -1 and post test-2 is shown in Table 2. The minimum value of right shoulder swing time is found during the fifteenth lap in pre test (0.354±0.02 seconds), first and fifteenth lap in post test-1 (0.376±0.03 seconds) and fifteenth lap in post test-2 (0.377±0.04 seconds).

ANOVA (Table 3) reveals that significant improvement in right shoulder swing time is witnessed in all the laps of 3000 m running except 3rd and 4th lap but Scheffe, revealed that this difference occurs only in 2nd, 4th to 12th and 14th and 15th laps of running in the pretest vs. post test- 1 group whereas pre test vs. post test-2 group shows

Table 2: Mean ± SD of right shoulder swing time (seconds) during 3000 m run

Variables	*Pre-test*	*Post-test-2*
Right Shoulder Swing Time at 1-Lap	0.362±0.03	0.397±0.03
Right Shoulder Swing Time at 2-Lap	0.366±0.02	0.383±0.03
Right Shoulder Swing Time at 3-Lap	0.375±0.02	0.382±0.03
Right Shoulder Swing Time at 4-Lap	0.381±0.02	0.396±0.03
Right Shoulder Swing Time at 5-Lap	0.376±0.02	0.398±0.03
Right Shoulder Swing Time at 6-Lap	0.377±0.02	0.401±0.03
Right Shoulder Swing Time at 7-Lap	0.377±0.02	0.399±0.03
Right Shoulder Swing Time at 8-Lap	0.381±0.02	0.400±0.03
Right Shoulder Swing Time at 9Lap	0.378±0.02	0.401±0.02
Right Shoulder Swing Time at 10-Lap	0.376±0.02	0.396±0.03
Right Shoulder Swing Time at 11-Lap	0.379±0.02	0.401±0.02
Right Shoulder Swing Time at 12Lap	0.378±0.02	0.396±0.02
Right Shoulder Swing Time at 13-Lap	0.378±0.02	0.395±0.02
Right Shoulder Swing Time at 14Lap	0.370±0.02	0.390±0.02
Right Shoulder Swing Time at 15-Lap	0.354±0.02	0.377±0.04

a significant improvement in right shoulder swing time in all the laps except 3rd lap. Post- test- 1 vs. Post- test – 2 groups reveals a significant change of right shoulder swing time only in the first lap of 3000 m run.

Left Shoulder Swing Time

The mean different left shoulder swing time during 3000m run before, after post- test -1 and post- test-2 is shown in Table 4. The minimum value of left shoulder swing time is found during the fifteenth lap in pre test (0.354±0.02 seconds), first lap in post- test-1 (0.372±0.03 seconds) and fifteenth lap in post- test-2 (0.369±0.03 seconds).

The results of ANOVA (Table 5) reveal that the left shoulder swing time during different laps of 3000m run increase after conditioning programme. In statistical terms that is the Scheffe test reveals that the change assumes significance in 10th lap and 14th lap of 3000 m run in the pretest vs. post test-I group, and 1st, 5th, 7th, 9th, 12th and 15th laps in the pre test vs. post test-II group.

Table 3: Analysis of variance right shoulder swing time during 3000 m run

Variables	*(SS)b*	*(SS)w*	*F-Value*
Right Shoulder Swing Time During 1-Lap	0.015	0.001	13.20*
Right Shoulder Swing Time During 2-Lap	0.004	0.001	3.94*
Right Shoulder Swing Time During 3-Lap	0.0008	0.001	0.68
Right Shoulder Swing Time During 4-Lap	0.002	0.008	3.05
Right Shoulder Swing Time During 5-Lap	0.006	0.008	8.54*
Right Shoulder Swing Time During 6-Lap	0.007	0.0009	7.95*
Right Shoulder Swing Time During 7-Lap	0.007	0.0009	8.52*
Right Shoulder Swing Time During 8-Lap	0.004	0.0007	5.93*
Right Shoulder Swing Time During 9-Lap	0.007	0.0006	10.99*
Right Shoulder Swing Time During 10-Lap	0.007	0.0007	10.06*
Right Shoulder Swing Time During 11-Lap	0.006	0.0006	9.62*
Right Shoulder Swing Time During 12-Lap	0.005	0.0006	8.10*
Right Shoulder Swing Time During 13-Lap	0.003	0.0006	5.31*
Right Shoulder Swing Time During 14-Lap	0.006	0.0006	9.52*
Right Shoulder Swing Time During 15-Lap	0.008	0.001	6.78*

*Significant at .05 level

Ratio of Right and Left Shoulder Swing Time

The mean value of ratio of right and left shoulder swing time (Table 6) during different laps of 3000 m run show a mixed trend of increase and decrease after a conditioning programme.

ANOVA (Table 7) and Scheffe reveal that a trend shown by the ratio of right and left shoulder swing time is statistically significant during 2nd lap, 4th lap, 7th lap, 9th lap, 10th lap, 12th lap and 15th lap in the pre test vs. post test-1 group and during 1st lap, 2nd lap, 11th lap, 14th lap and 15th of the run in pre test vs. post test-2. Similarly the post- test-1 vs. post- test-2 group shows statistically significant changes in the ratio between right and left shoulder swing times during 1st lap and 12th lap of 3000 m run.

The multiple regression analysis by considering total performance time of 3000 m run as dependent variable and right and left shoulder swing time during each lap of 3000 m run as independent variable in pre- test, post- test-1 and

Table 4: Mean ± SD of left shoulder swing time (seconds) during 3000 m run

Variables	*Pre-test*	*Post-test-I*	*Post-test-II*
Left Shoulder Swing Time at 1-Lap	0.363±0.03	0.372±0.03	0.381±0.03
Left Shoulder Swing Time at 2-Lap	0.367±0.02	0.378±0.04	0.377±0.04
Left Shoulder Swing Time at 3-Lap	0.375±0.02	0.375±0.04	0.377±0.04
Left Shoulder Swing Time at 4-Lap	0.382±0.02	0.383±0.03	0.393±0.03
Left Shoulder Swing Time at 5-Lap	0.376±0.02	0.388±0.03	0.393±0.03
Left Shoulder Swing Time at 6-Lap	0.377±0.02	0.391±0.03	0.397±0.03
Left Shoulder Swing Time at 7-Lap	0.377±0.02	0.386±0.03	0.392±0.03
Left Shoulder Swing Time at 8-Lap	0.381±0.02	0.391±0.03	0.395±0.02
Left Shoulder Swing Time at 9-Lap	0.379±0.02	0.391±0.02	0.395±0.02
Left Shoulder Swing Time at 10-Lap	0.376±0.02	0.391±0.02	0.394±0.03
Left Shoulder Swing Time at 11-Lap	0.380±0.02	0.391±0.02	0.394±0.02
Left Shoulder Swing Time at 12-Lap	0.378±0.02	0.384±0.03	0.393±0.02
Left Shoulder Swing Time at 13-Lap	0.379±0.02	0.387±0.02	0.390±0.03
Left Shoulder Swing Time at 14-Lap	0.370±0.02	0.385±0.02	0.383±0.02
Left Shoulder Swing Time at 15-Lap	0.354±0.02	0.368±0.03	0.369±0.03

Table 5: Analysis of variance left shoulder swing time during 3000 m run

Variables	*(SS)b*	*(SS)w*	*F-Value*
Left Shoulder Swing Time During 1-Lap	0.004	0.001	3.28*
Left Shoulder Swing Time During 2-Lap	0.001	0.001	1.45
Left Shoulder Swing Time During 3-Lap	0.00006	0.001	0.05
Left Shoulder Swing Time During 4-Lap	0.002	0.0008	2.36
Left Shoulder Swing Time During 5-Lap	0.004	0.0009	4.06*
Left Shoulder Swing Time During 6-Lap	0.005	0.001	4.90*
Left Shoulder Swing Time During 7-Lap	0.003	0.0009	31.3*
Left Shoulder Swing Time During 8-Lap	0.002	0.0008	2.99
Left Shoulder Swing Time During 9-Lap	0.003	0.0006	5.20*
Left Shoulder Swing Time During 10-Lap	0.004	0.0007	6.21*
Left Shoulder Swing Time During 11-Lap	0.002	0.0005	4.36*
Left Shoulder Swing Time During 12-Lap	0.003	0.0007	3.93*
Left Shoulder Swing Time During 13-Lap	0.001	0.0007	2.15
Left Shoulder Swing Time During 14-Lap	0.003	0.0006	5.10*
Left Shoulder Swing Time During 15-Lap	0.003	0.001	3.18*

*Significant at .05 level

post test-2 shows that during pre- test, post- test-I and post test-II, the order of entered variables in regression analysis is different from each other and all of them give a non-significant R^2 and F-statistic at .05 level and their respective values are R^2 = 0.52584 and F= .981; R^2 = 0.46695 , F = 0.554 and R^2 = 0.606629, F =0.975. Although there is no statistical significant F- statistic gi-

Table 6: Mean ±SD of Ratio between right & left shoulder swing time during 3000m run

Variables	*Pre-test*	*Post-test-I*	*Post-test-II*
Ratio between Right and Left Shoulder Swing Time at 1-Lap	0.99±0.01	1.01±0.04	1.04±0.03
Ratio between Right and Left Shoulder Swing Time at 2-Lap	0.99±0.01	1.01±0.04	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 3-Lap	0.99±0.01	1.01±0.06	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 4-Lap	0.99±0.02	1.02±0.04	1.00±0.04
Ratio between Right and Left Shoulder Swing Time at 5-Lap	1.00±0.01	1.02±0.06	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 6-Lap	1.00±0.02	1.01±0.05	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 7-Lap	1.00±0.01	1.03±0.06	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 8-Lap	1.00±0.01	1.01±0.04	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 9-Lap	0.99±0.01	1.01±0.05	1.01±0.02
Ratio between Right and Left Shoulder Swing Time at 10-Lap	1.00±0.01	1.01±0.04	1.00±0.02
Ratio between Right and Left Shoulder Swing Time at 11-Lap	0.99±0.02	1.00±0.03	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 12-Lap	1.00±0.01	1.03±0.07	1.00±0.03
Ratio between Right and Left Shoulder Swing Time at 13-Lap	0.99±0.02	1.00±0.06	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 14-Lap	0.99±0.01	1.00±0.04	1.01±0.03
Ratio between Right and Left Shoulder Swing Time at 15-Lap	1.00±0.01	1.02±0.05	1.02±0.04

Table 7: Analysis of variance of ratio between right and left shoulder time during 3000m run

Variables	*(SS)b*	*(SS)w*	*F-Value*
Ratio Between Right and Left Shoulder Swing Time During 1-Lap	0.026	0.001	21.05*
Ratio Between Right and Left Shoulder Swing Time During 2-Lap	0.005	0.001	4.68*
Ratio Between Right and Left Shoulder Swing Time During 3-Lap	0.005	0.001	3.17*
Ratio Between Right and Left Shoulder Swing Time During 4-Lap	0.006	0.001	4.12*
Ratio Between Right and Left Shoulder Swing Time During 5-Lap	0.004	0.001	2.85
Ratio Between Right and Left Shoulder Swing Time During 6-Lap	0.001	0.001	1.34
Ratio Between Right and Left Shoulder Swing Time During 7-Lap	0.01	0.001	6.36*
Ratio Between Right and Left Shoulder Swing Time During 8-Lap	0.001	0.001	1.72
Ratio Between Right and Left Shoulder Swing Time During 9-Lap	0.005	0.001	3.96*
Ratio Between Right and Left Shoulder Swing Time During 10-Lap	0.004	0.001	3.97*
Ratio Between Right and Left Shoulder Swing Time During 11-Lap	0.005	0.0009	5.62*
Ratio Between Right and Left Shoulder Swing Time During 12-Lap	0.012	0.002	5.68*
Ratio Between Right and Left Shoulder Swing Time During 13-Lap	0.002	0.001	1.42
Ratio Between Right and Left Shoulder Swing Time During 14-Lap	0.004	0.0009	4.40*
Ratio Between Right and Left Shoulder Swing Time During 15-Lap	0.006	0.001	4.11*

*Significant at .05 level

ven by the order of variables entered in regression analysis during pre- test, post- test-1 and post-test-2, but the left shoulder swing time in the fifteenth lap of 3000m run indicate its importance to the total performance time in 3000 m run.

DISCUSSION

Three thousand meter running involves movements of the legs, arms, trunk etc. in a well-coordinated and cyclic manner both at steady pace of running as well as accelerated movements resembling sprint running in the last phase of the race. The conditioning programme has resulted in significant changes in the abilities of the subjects to move the shoulder (right and left) that is increase their swing time.

These improvements in the shoulder swing time during various laps of 3000m reasonably suggest that the conditioning programme has caused self-optimization process to develop movement patterns that require minimum energy and exert less stress to the body. Svedenhag and Sjodin (1985) observed that with training athletes developed slow but steady improvements in the running economy. It is reported that several running style variables influence running economy and further suggested that adjustments in running mechanics may improve economy and possible performance (Williams and Cavanagh 1987; Morgan et al. 1988). Literature has also provided support for the relationship between mechanical and physiological variables, showing that more economical runners tend to have identifiable patterns in their running mechanics (Williams and Cavanagh 1987; William et al. 1987). Brisswalter et al. (1996) observed that with training athletes developed slow but steady improvements in the running economy.

In the last lap of 3000 m run, because of its sprint nature, the body segments must undergo high angular accelerations to place the body in a position necessary to sustain sprint. The results of the present study attach significance to the swinging movement of the upper extremity that is shoulder swing and arm movements in running performance. This is understandable because vigorous back swing of arms causes the legs to stride further. According to Dyson (1970), the arms act as spur on the legs which speed up and consequently add to their horizontal drive. Schmolinsky (1978) are of the view that body rhythmic movements and the arms assist the runner to maintain the stride rhythm. In general, mechanical swinging movement of the arms help the main movement in a number of ways. It can increase the momentum of the main movement, it can produce rotational effect or it can help in maintaining the balance. Bhowmick and Bhattacharyya (1988) concluded that the horizontal component of arm swing increase the stride length. Thus, the role of shoulder swing as an important determinant in the last lap of 3000 m running distance is justified.

These rotary actions of shoulder evoke contrary reaction in the athletes lower body, for, as the athletes left shoulder along with the arm swings forward and upward, his right knee is swung forward and upward and his right shoulder along with arm backward and upward to balance this leg action. Then as the right foot is lowered and the left leg starts to move forward, the actions of the arm are reversed. Although, the hip also rotates to balance the shoulder action but such rotations are relatively high. Thus, to avoid the complications of slowness of shoulder movements, good runners might use an arm action of such a range that there is an equality between hip action and upper body (that is, shoulder) reaction. In this arm action, the arms are flexed to about right angle at the elbow and swing backward, forward and slightly inward about an axis through the shoulder. At the forward limit of shoulder swing, the hands are at about shoulder height and at the backward limit is level with the hip. The rapid arm movements contribute towards the horizontal velocity and thus speed of running. Analysis of the results of the present study in the light of discussion given above can be viewed as positive effects of conditioning programme in improving the 3000m running performance.

Clearly in a group of runners with homogeneous physiological determinants, performance will be largely determined by economy. Since biomechanical factors are important in economical running and will also be determinant of running performance. In this study, the increase in the shoulder swing time during running may be the subject's attempt at self- optimization of biomechanical aspects of running style as it acts as a fine tuning device to both energy expenditure and performance much in the same way that specific training regimen might fine tune the physiological systems. The conditioning programme because of its constituents like stretching, aerobic and speed components have been successful in producing the requisite biomechanical changes and thus running performance.

CONCLUSION

It is concluded that the three months conditioning programme has revealed statistically significant impact on right and left shoulder swing time, ratio of right and left shoulder swing time and performance time of 3000m run. These improvements reasonably suggest that the conditioning programme has caused a process of self-optimization of biomechanical aspects of running style to develop such a movement pattern which act as a fine tuning device to both energy expenditure and performance and thus improved performance time of 3000m running.

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