THE BIOMECHANICAL EFFECTS OF TREADMILL TRAINING ON RUNNING PERFORMANCE

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ABSTRACT

The biomechanics of overground running were compared before and after a month training period which comprised 16 thirty-minute sessions of short duration (5 seconds work, 10 seconds rest) high intensity (4.69 m/sec 20-25% grade) interval treadmill work. For the eight subjects filmed there were no significant changes in support and non support time, stride length or stride rate while running at 3.58 m/sec that could be attributed to the treadmill training regime. This training programme produced significant gains in aerobic and anaerobic metabolism but was not an effective developer of speed.

INTRODUCTION

The motor driven treadmill has long been used in the laboratory situation to provide a standard and reproduceable work performance. This makes it ideal for controlling the training intensity of athletes involved in running sports. However, biomechanical differences have been shown to exist between treadmill and overground running techniques (8).

Hence, while it may be possible to obtain some desirable physiological changes in athletes training on the treadmill, the practice of a different running action may produce deleterious effects on running efficiency when reverting to the overground situation.

The purpose of this study was to investigate changes in selected aspects of the biomechanics of overground running following a period of intensive treadmill training.

METHODS

Subjects

Eight male physical education graduate students, who agreed to refrain from all regular physical exercising other than the specific training requirements, were trained and tested. Their ages ranged from 23 to 35 years (mean 28 years), their height from 172.5 to 184.9 centimetres (mean 178.6 cms) and their weight from 65.9 to 86.4 kilograms (mean 75.1 kgs). All subjects were experienced in treadmill running thus avoiding the problems of habituation noted in studies by Davies and Knibbs (2) and Eddy et al., (3). However, no subjects were regular competitors in track or cross-country running.

Training Programme

Subjects were required to train on a motor driven treadmill four times weekly for one month. Each training session consisted of intermittent activity (5 sec work, 10 sec rest) at 4.69 m/sec (10.5 mph) up a 20% grade. The duration of the work and rest periods was designed to permit a high total work output by limiting the anaerobic breakdown of glycogen to lactic acid. Subjects were required to perform as many five second work periods as possible within a thirty minute period. The subject stood alongside the treadmill during each rest period and attempted to complete as many 5 second work periods as possible within the specified format. If a subject completed the maximum number of 120 work periods in two separate training sessions he continued the regime at the same speed up a 25% treadmill grade.

Filming techniques

This experiment was designed and conducted so that pre and post training test conditions on the overground and treadmill surfaces were duplicated. The subjects ran at 3.58 m/sec (8 mph) on the level track and treadmill. This is a standard running speed commonly used for submaximal physiological assessments. The second set of measurements was obtained during a maximal track sprint. Running on the treadmill up a 20% grade at 4.69 m/sec was also studied as this constituted the training work rate. The pre training filming of overground running (0% grade, 3.58 m/sec) overground sprinting and treadmill running (0% grade, 3.58 m/sec; 20% grade, 4.69 m/sec) was accomplished at one test session.

Treadmill speed was checked for each subject by timing the belt for ten revolutions. During overground running (3.58 m/sec) the subjects regulated their speed by reaching markers on a pathway (placed 14.3 m. apart) in synchrony with a timed auditory signal, which was manually operated to sound every four seconds. Adjustments to running speed were made before the subject entered the film area.

At the end of four weeks (sixteen sessions) of training the filming was repeated following the same standardised procedures used in the pre training sequence.

A Bolex H16 movie camera, using 200 ASA film, and operating at 64 frames per second was used in all filming. The camera was secured on a tripod and positioned so that the focal axis of the 25 mm Switar lens was perpendicular to the plane of locomotion. The distance to the subject was 5 m. (16.4 feet) 15.2 m. (50 feet) and 18.3 m. (60 feet) for treadmill running, overground running and sprinting, respectively. These distances were selected so that the maximum number of strides could be filmed without moving the camera or incurring perspective errors by setting the angle of filming at greater than 25^{o} (10).

Film analysis procedures were based on the directives of Gombrac (5). All distance measurements taken from the film were adjusted in order to convert them to "life size." A hurdle of known length was placed perpendicular to the axis of filming for this purpose. By comparing the actual size and the projected size a multiplier was determined which was then applied to distances measured from the film.

Camera speeds were calibrated by filming a ball dropped from a known height. Time was calculated by dropping the ball from a height of one metre and knowing that gravity at the filming site was 9.79 m/sec.^{2}. Film speed was then determined by counting the number of frames of film required for the ball to drop when filmed at right angles to the line of flight. The camera was rewound for each subject and film speed was continually checked against the known treadmill belt speed.

Analysis of the film was accomplished by using an Analector movie projector and an X, Y co-ordinate board that was moveable in both planes and attached to a wall. This system provided a large image (1:11 image: life) thus helping to reduce measurement error and permitting reliable frame alignment.

Film Analysis

Guidelines for the biomechanical analysis of running can be found in many articles in the literature (6, 11). Four variables were chosen for analysis, because they were biomechanically relevant and could be measured accurately with the equipment available. Definitions of each of the four variables, support phase, non-support phase, stride length and stride rate are:

1. **Support Phase:** the support phase time period (measured in fps and converted to time) was determined from the moment of heel contact until toe-off of the same foot. Each subject had four consecutive strides (two cycles) analysed for all but the sprint where only two strides (one cycle) were filmed. A mean value was then calculated for each subject.

2. **Non-support Phase:** the non-support phase time period was determined from toe-off of one foot to heel contact of the other foot. The method of analysis was the same as for the support phase.

3. **Stride Length:** for overground running stride length was defined as the horizontal distance that was covered in one stride along the running surface. Measurements were taken from the toe at foot strike (foot strike was defined as that point of contact with the ground when the tibia was as close to perpendicular to the ground as the number of film frames allowed) (1) to the same position at the completion of one stride cycle. This measurement was then halved to give stride length in preference to taking either the right or left strides as being representative of a particular subject although consistency of stride length for any individual subject was evident during first pre and then post-training analysis. Stride length on the treadmill was calculated by adding together the period of support and non-support and mutliplying this figure by the speed of the treadmill belt in metres per second. The mean for two consecutive strides was determined for each individual for both overground and treadmill running.

4. **Stride rate:** for both treadmill and overground running, stride rate was defined as the reciprocal of the sum of support and non-support phases averaged over two consecutive strides.

In order to minimise the influence of error any subject whose velocity varied by more than 0.2 m/sec in comparing pre and post velocities was eliminated.

Statistical Analysis

Any differences between pre and post-training values were assessed by the application of t tests for related groups using the direct difference method (4).

For a given sample size and significance level the t test is the uniformly most powerful statistic and therefore to minimise the possibility of a Type I or Type II error the 0.05 level of confidence was established (7).

RESULTS AND DISCUSSION

No significant changes were observed in support and non-support time, stride length and stride rate during track sprinting, track or treadmill running on the level at 3.58 m/sec, or treadmill running at 4.69 m/sec up a 20% grade following the one month period of intensive treadmill training (see Tables I to IV).

When comparing overground running at 3.58 m/sec two subjects were eliminated from the analysis as their pre and post-training varied by more than 0.2 m/sec. Mean velocities of 3.65 m/sec and 3.67 m/sec respectively were recorded from film analysis of pre and post overground running while mean sprint velocities of 9.28 m/sec and 9.38 m/sec were obtained cinematographically when comparing sprinting both before and after training.

It is interesting to note the physiological adjustments made by the men to the training programme. While oxygen consumption, pulmonary ventilation and blood lactate accumulation during a standard 10 minute run at 3.58 m/sec were unchanged, steady state heart rate during this work decreased by 5.4%. Oxygen consumption during exhausting work increased from 51.2 to 54.2 ml/kg X min ($P > 0.05$). There were no significant improvements in either a short sprint or a stair-climbing test that assessed the ability to generate mechanical power. (Pyke et al)* Thus the training method produced significant improvement in aerobic and anaerobic metabolism but was not an effective developer of speed. From a practical point of view it is therefore more critical to evaluate biomechanical factors in the endurance task of running at 3.58 m/sec overground than it is to be concerned with track sprinting.

It is perhaps of some relief to coaches that treadmill training up a steep grade does not alter the biomechanical features of the sub-maximale track running gait.

Unfortunately the energy cost of sub-maximale overground running was not determined hence the lack of change in the biomechanical variables could not be substantiated by lack of change in physiological variables. However, two points should be noted. Firstly it is possible that biomechanical changes in other factors not considered in this inevstigation such as angle of body lean, knee angle and the ball/heel relationship in the foot at touchdown may contribute detrimentally to track distance running performance. Secondly it is necessary to undertake further study of all of these factors while running at faster speeds. Championship 10,000 metre running speeds, for example, are in excess of 5.6 m/sec., which is substantially faster than that studied here.

It was also of interest to observe the non-significant effects of treadmill training on these same biomechanical variables measured while running on the treadmill at 3.58 m/sec. This is substantiated by the unaltered energy cost ($\dot{V}O_2$) of running at this speed. However a trend does appear in the data comparing the pre- and post-training times for period of support and non-support on the treadmill while running at 3.58 m/sec. On both the 0% and 20% grades the period of support increased while the period of non-support decreased.

SUMMARY AND CONCLUSIONS

During a one month training period, eight active men aged 23-35 years completed 16 thirty minute sessions of short duration (5 sec work, 10 sec rest) high intensity (4.69 m/sec 20-25% grade) interval treadmill work.

It was concluded that this type of training produced no significant changes in support and non-support time, stride length, or stride rate during track sprinting, track running at 3.58 m/sec, treadmill running on the level at 3.58 m/sec or treadmill running up a 20% grade at 4.69 m/sec.

TABLE I

Effects of Treadmill Training on Support Phase (Sec.) during Treadmill and Overground Running

	OVERGROUND				TREADMILL			
	0% Grade 3.58 m/sec		0% Grade Sprint		0% Grade 3.58 m/sec		20% Grade 4.69 m/sec	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
$\overline{X}$	0.271	0.267	0.118	0.117	0.245	0.255	0.197	0.208
S.D.	0.010	0.008	0.014	0.011	0.014	0.013	0.021	0.010
t	0.647*		0.287		2.132		1.851	
p	N.S.		N.S.		N.S.		N.S.	

*n = 6

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TABLE II

Effects of Treadmill Training on Non-Support Phase (Sec.) Obtained during Treadmill and Overground Running

	OVERGROUND				TREADMILL			
	0% Grade 3.58 m/sec		0% Grade Sprint		0% Grade 3.58 m/sec		20% Grade 4.69 m/sec	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
$\bar{X}$	0.094	0.102	0.123	0.126	0.123	0.113	0.096	0.087
S.D.	0.016	0.016	0.010	0.015	0.018	0.013	0.015	0.011
t	1.874*		0.958		1.777		0.034	
p	N.S.		N.S.		N.S.		N.S.	

*n = 6

TABLE III

Effects of Treadmill Training on Stride Length during Treadmill and Overground Running

	OVERGROUND				TREADMILL			
	0% Grade 3.58 m/sec		0% Grade Sprint		0% Grade 3.58 m/sec		20% Grade 4.69 m/sec	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
$\bar{X}$	1.351**	1.330	2.236	2.286	1.319	1.318	1.374	1.384
S.D.	0.064	0.058	0.123	0.143	0.055	0.043	0.109	0.087
t	1.077*		1.004		0.095		0.310	
p	N.S.		N.S.		N.S.		N.S.	

* n = 6
** metres

TABLE IV

Effects of Treadmill Training on Stride Rate during Treadmill and Overground Running

	OVERGROUND				TREADMILL			
	0% Grade 3.58 m/sec		0% Grade Sprint		0% Grade 3.58 m/sec		20% Grade 4.69 m/sec	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
$\bar{X}$	2.741**	2.713	4.156	4.146	2.706	2.720	3.438	3.400
S.D.	0.127	0.091	0.271	0.340	0.114	0.092	0.257	0.221
t	0.761*		0.081		0.397		0.442	
p	N.S.		N.S.		N.S.		N.S.	

*n = 6
** Strides/sec.

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