WORK-ENERGY ANALYSIS OF TRIATHLETES RUNNING UNDER BIKE/RUN AND RUN ONLY CONDITIONS

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INTRODUCTION

The biomechanics of running have been well documented over the past several decades and considerable material on both the kinematics and kinetics of competitive and recreational running is available. This extends to the efficiency or economy of running but unfortunately, it appears, not to the efficiency of the running triathlete. The triathlon is a rapidly developing competitive sport requiring proficiency in swimming, cycling, and running. As such, triathletes are required to run long distances following extended periods of other forms of exercise. Specifically, a long distance run normally follows a cycling race. At present, it appears that little research has focused on the effects of this prior activity on the mechanics of the run portion of a triathlon. No evidence has been found of attempts to look at the work-energy characteristics of the run portion of a triathlon. The purpose of the study, therefore, was to determine if a triathlete's running mechanics are altered at various intervals during a 10 km run or if they are altered by having just completed a 40 km bike ride. Specifically, an attempt was made to focus on both the kinematics of triathlete running as well as the work-energy characteristics of the running motion at various points during a run and in runs made under different conditions.

METHODOLOGY

There were two independent variables in this study. The first was an interval variable as runners were evaluated at 1 km, 5 km, and 9 km intervals during each of two 10 km runs. The second independent variable was a condition variable. Subjects ran two 10 km runs at as close to race pace as possible. In one condition the run was preceded by a short warm-up while in the other it followed a 40 km, race pace, bike ride. Thus, the basic design of the study was a two-factor experiment with repeated measures on both factors.

The dependent variables measured fell into two categories; these included kinematics of running as well as work-energy characteristics. The kinematic variables measured were running velocity, stride length and stride rate. The energy analysis included measures of total energy, work, work rate, and passive energy exchanges both within and between segments.

Five skilled male triathletes ranging in age from 23 to 33 years volunteered to participate in the study. All were regular triathlon competitors and testing was carried out at or near peak training periods in each case. Short portions of each of the two runs of each subject was filmed using a Locam 16 mm camera operating at a speed of 50 Hz. The race course was set such that the runners passed through the filming area at each of the 1 km, 5 km, and 9 km intervals. In each case at least one full cycle of running was filmed. Raw segment end-point data were collected from film through use of an Altek AC30 digitizer and were processed using a Butterworth, fourth order, low pass digital filter with a cutoff to sampling frequency ratio of 1 to 10. Both kinematic and work-energy data were collected for each trial under both conditions and at the three intervals. The work-energy analysis was completed using the methods of Pierrynowski et al. (1980) which included the determination of work values and rates under a number of assumptions as well as the computation of passive energy exchanges both within and between segments. Each kinematic and work-energy dependent variable was evaluated for both condition and interval effects as well as interaction using a 2 X 3 Analysis of Variance with repeated measures. Statistically significant differences were accepted at $p<0.05$.

RESULTS

The running velocities and stride lengths of the subjects at each interval and under each condition are listed in Table 1.

Table 1. Running velocity and stride length (n = 5).

	Running Velocity		Stride Length	
	Run Only *	Bike/Run	Run Only *	Bike/Run
1 km	6.65 m/s	4.28 m/s	1.98 m	1.50 m
5 km	6.38 m/s	4.32 m/s	1.96 m	1.51 m
9 km	6.83 m/s	4.24 m/s	2.11 m	1.47 m

* Significant differences between conditions at $p<0.05$

It is apparent that triathletes run significantly slower during a run following a 40 km bike race than when running following a short warm-up. There were no significant differences between velocities recorded at the various intervals and there was no statistically significant interaction effect. These differences in velocity were accompanied by parallel differences in the length of the running stride. There was a significant difference between conditions but no differences between intervals and no interaction effect. The mean stride rates at each interval in the run only condition were 3.36, 3.26, and 3.24 strides per second and in the bike/run condition the stride rates were 2.85, 2.86, and 2.88 strides per second. While the trend shows that runners are able to achieve higher rates of striding in a normal run in comparison to a run following a bike race, the variability among subjects was high and the differences between conditions did not meet the criteria for statistical significance.

The internal mechanical work rates, assuming that energy is transferred passively within the body (RWw_b), as well as the actual values for energy transfer rate accounting for both within and between segment transfers (RT_{wb}) are listed in Table 2.

Table 2. Internal mechanical work rate and energy transfer rate (n = 5).

	Run Only		Bike/Run	
	RW_{wb} **	RT_{wb}	RW_{wb} **	RT_{wb}
1 km	669.0 *	2060.2	707.9 *	2136.7
5 km	390.3	1901.3	361.8	1718.2
9 km	377.0	2024.5	579.1	1746.9

** Statistically significant condition effects at $p<0.05$

* Statistically significant interval effects under both conditions at $p<0.05$

It was apparent that, on average, the rate of internal work (RWwb) was significantly higher in the bike/run event than in the run only event. This likely occurred because of the slightly lower rates of energy transfer in the bike/run trials. However, due to the high variability there were no significant differences in the rate of energy transfer. When the total mechanical energy values were computed for all segments it was found that all segments had significantly higher energy levels in the run only condition. For example, at the 1 km interval the mean total thigh energy was 615.1 J in the run only condition and only 371.3 J in the bike/run condition. At the 9 km interval the corresponding values were 624.4 J and 395.1 J respectively. Similar trends were also found for the arm, forearm, shank, and trunk segments. This finding was expected since the run only trials exhibited significantly higher running velocities.

DISCUSSION

As might be expected, a 10 km run which occurs following a 40 km bike race is run at a significantly lower velocity than a normal 10 km race. It appears that the main factor differentiating between the two conditions is the length of stride achieved by subjects. There was no significant difference in the rate of striding. The fact that the run only condition was performed at higher velocities also contributed to the significantly higher mechanical energy values of all segments during that condition. On the other hand, when passive energy transfers were accounted for, the work rate associated with internal work was higher in the bike/run condition. In effect, the runners had to do more muscular work in the bike/run condition than in the run only condition and still did not achieve similar velocities. No doubt fatigue plays a role in determining the forcefulness of muscular contraction which, in turn, has an effect on stride length. It was interesting to note that there were no significant interval effects for either velocity or stride length. This would indicate that each run was performed fairly consistently. On the other hand, there was a significant interval effect for the rate of internal work indicating that at the middle portion of the 10 km run, the rate of working had decreased. However, as the runners approached the end of the run they were able to increase their work rates to levels closer to those at the beginning of the run. These differences are possibly due to motivational or other factors as they can not be explained by the work and energy transfer results of this study.

CONCLUSIONS

In summary, selected running mechanics of skilled triathletes were evaluated under two conditions and at three intervals during 10 km runs. Based on the results of the study and with the limitations of the study in mind, the following conclusions are warranted:

1. Triathletes run with higher horizontal velocities and longer strides in a run only condition as compared to a run following a 40 km bike race.
2. Triathletes do more internal mechanical work when running following a 40 km bike race than in a run only condition.
3. There are no significant differences in passive energy exchange or in the rate of energy exchange in the running mechanics of triathletes performing a run only in comparison to a run following a 40 km bike race.

REFERENCES

Pierrynowski, M. R., Winter, D. A., Norman, R. W. (1980). Transfers of mechanical energy within the total body and mechanical efficiency during treadmill walking. Erg 23(2):147-156.