A BIOMECHANICAL AND PHYSIOLOGICAL ANALYSIS OF EFFICIENCY AT DIFFERENT RUNNING PACES

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INTRODUCTION

Efficiency is described as how much energy must be expended to produce a measurable amount of work. The theory of efficiency is one that has intrigued coaches and athletes during competitive training. Although efficiency has been measured in running, researchers did not study efficiency during extended periods of exercise at different intensities. Bunc et al. (1986) suggested that the differences in efficiency could be explained by running style and number of years of training.

The purpose of this study was to investigate the differences between selected biomechanical and physiological parameters in treadmill running at both an easy running pace and at race pace. Biomechanical and physiological data were analyzed during two 15 minute runs which were running at subject selected speeds. The following research questions were investigated in this study: a) How do observable biomechanical factors differ between easy pace and race pace? b) When do metabolic parameters change during an extended treadmill protocol? c) Is efficiency adversely affected at approximately the same time for all subjects?

METHODOLOGY

The data collection process involved two separate testing sessions. The initial session included signing an informed consent form, completing a medical history questionnnaire, hyperventilation test, and a modified Astrand test to determine maximal oxygen consumption. Blood lactate samples were collected pre- and post exercise bout.

The second session included both a 15 minute easy pace and a 15 minute race pace on a treadmill. The speed remained constant during the exercise bout and the grade was level. Physiological variables analyzed during this time included: a) heart rate; b) R value; c) VO_2; d) percent of VO_{2max}; and e) blood lactate. The physiological data were collected continuously during the exercise bout. The biomechanical variables included: a) stride frequency; b) stride length; c) time of stride; and d) percent of support. Film data were collected at 100 fps at 5 and 15 minutes of exercise. The physiological and cinematographic data were matched at both paces and times so that efficiency measurements could be calculated. Processed film was analyzed by a Vanguard projector, a Numonics digitizer, and a microcomputer. A data file was established for all segmental endpoints for all frames. The data points were digitized by utilizing a software program written by Noble et al. (1988).

Data were statistically analyzed with a two-by-wo factorial design. The pace variable was easy or race and the time variable was a 5 minute trial or a 15 minute trial. Both factors were within-subject factors. The dependent variables in the study were the biomechanical variables, metabolic variables, and efficiency.

RESULTS

The ANOVA results for the biomechanical hypotheses indicated that there were no significant interactions for any of the biomechanical variables. A trend did exist between the independent and dependent variables. Stride length and stride frequency increased with an increase in time and intensity. Percent of support and time of stride decreased with an increase in time and intensity of exercise. For the pace main effect, each of the biomechanical variables was significant at the .001 level.

The statistical design used to measure the metabolic hypotheses indicated similiar results. Although the interaction of time and pace was not significant (alpha > 0.05) for any of the metabolic variables, a trend did exist for HR, LA, VO2 (ml/kg/min), and $\%VO_{2max}$. With an increase in time and pace, there was an increase in the value of each physiological variable. Evaluation of the time differences showed a significant difference for lactate level at $p = 0.003$. None of the other variables were significant. For the pace main effect, heart rate, lactate level, VO_2 (ml/kg/min), and $\%VO_{2max}$ were significant at the 0.001 level.

Neither the time by pace interaction for efficiency or the time main effect was significant. For the pace effect, efficiency was significant at $p = 0.001$ level.

DISCUSSION

The changes in the biomechanical variables were similiar to that in other studies. Alexander and Thiessen (1983) suggested that trained runners altered their stride length and stride frequency parameters to minimize energy cost at a particular speed. These mechanical factors were also altered by the runners with increases in running pace. The mean stride length increased from the easy pace to the race pace as did the stride frequency.

Changes in the physiological variables studied in this study were consistent with previous literature. Variations in the levels of blood lactate and $\%VO_{2max}$ might have been affected by differences in training levels and intensity.

The efficiency values obtained in this study were higher than reported in previous studies. The efficiency values decreased in race pace trials because the athletes were nearer their VO_{2max}. This finding is also supported in the literature by Donovan and Brooks (1977).

CONCLUSIONS

Upon analysis of each research hypothesis and within the scope and limitations of this study, it may be concluded that the effect of time does not significantly influence biomechanical, physiological, and efficiency responses in treadmill locomotion. It can also be concluded that the pace does produce a significant difference among biomechanical, metabolic, and efficiency variables. In summary, it was concluded that efficiency is not a function of time. The time of data collection did not appear to significantly affect the dependent biomechanical or physiological variables. It was also concluded that efficiency is a function of pace. The intensity of the trial did affect the dependent variables and also the total body efficiency.

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