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Cardiovascular Responses During Groucho Running

ANTHONY SKIME, TOMMY BOONE

Department of Exercise Physiology, The College of St. Scholastica

#### ABSTRACT

Skime A, Boone T. Cardiovascular Responses During Groucho Running. **JEPonline** 2011;14(2):88-92. The purpose of this study was to determine the steady-state cardiovascular effects of 10 min of Groucho running. In randomized order, 6 subjects participated in both the Control Session (normal running) and the Treatment Session (Groucho running). Oxygen consumption  $(VO_2)$  and cardiac output (Q) were determined using a Cardio2 metabolic analyzer. Cardiac output was determined at the end of the 10th min of the exercise period using the CO<sub>2</sub> rebreathing procedure. The physiological data were analyzed using the ANOVA with repeated measures. Groucho running resulted in a significant increase in Q (p < 0.05), which significantly increased VO<sub>2</sub>. The Q response was due to the significant increase in heart rate (HR) since stroke volume (SV) was unchanged. The increase in metabolic rate was coupled to the increase in Q, which was achieved by the significant increase in mean arterial pressure (MAP). The increase in VO<sub>2</sub> was associated with an increase in expired ventilation ( $V_E$ ), which was a result of a significant increase in the frequency of breaths (Fb). There were no significant changes in steady-state tidal volume  $(T_V)$ , arteriovenous oxygen difference (a-vO<sub>2</sub> diff), and peripheral vascular resistance (PVR) during Groucho running. These findings indicate that the increase in  $VO_2$  during Groucho running resulted from a central adjustment in the steady-state Q response and not from a peripheral adjustment in tissue extraction.

**Key Words**: Groucho Running, Oxygen Consumption, Heart Rate, Stroke Volume, Cardiac Output, Arteriovenous Oxygen Difference

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## INTRODUCTION

It is understood that the stiffness in the lower extremities play a role not just in terms of speed but also in terms of running economy. Groucho running is defined as running with a dramatic increase in knee flexion that increases the reaction moments acting on the knee joints. As McMahon and colleagues [8] pointed out, from an injury-prevention standpoint, Groucho-style running reduces the shock which is transmitted up through the body during the foot strike. But, with the longer foot contact time, there is an increase in the oxygen cost of running at a particular speed. As a result, somewhat stiff athletes tend to have better running economy than very flexible runners [2].

While it is known that Groucho running [8] significantly increases oxygen consumption (VO<sub>2</sub>), less information is available on the central (heart rate, HR; stroke volume, SV; cardiac output, Q) and peripheral components (arteriovenous oxygen difference,  $a \cdot vO_2$  diff) of steady-state VO<sub>2</sub>. There are also questions about the ventilatory response (minute ventilation, V<sub>E</sub>) during Groucho running. Thus, the purpose of this study was to determine the effects of Groucho running on the central and peripheral components of VO<sub>2</sub> and V<sub>E</sub> during submaximal treadmill exercise in college-age subjects. To our knowledge, this particular analysis has not yet been carried out although the original study was published 1987. We hypothesized that V<sub>E</sub> is likely to increase and, therefore, should contribute to an increase in the energetic cost (VO<sub>2</sub>) of running. Of course the question is whether the increase in VO<sub>2</sub> is directly related to an increase in Q as a central adjustment to Groucho running or is it a peripheral adjustment (a-vO<sub>2</sub> diff).

## METHODS

#### Subjects

A homogeneous group of healthy subjects (2 males and 4 females) gave voluntary consent to participate in this study. All subjects were nonsmokers, and none was taking any medication. They participated only in educational and noncompetitive athletic activities. This allowed for similar diets and daily expenditure of energy before and on the two days of assessment. The subjects' mean ( $\pm$ SD) age, body mass, and height were 21  $\pm$  1 yr, 71.2  $\pm$  3 kg, and 176  $\pm$  4 cm, respectively. The Human Subjects Committee of the The College of St. Scholastica approved the study.

#### Design of the Study

Each subject was provided instructions regarding data collection and familiarization with the Exercise Physiology Laboratory prior to the study. During the session, the subjects practiced at running with increased knee flexion on a treadmill. On arriving at the laboratory at 10 a.m., each subject sat quietly 5 min. The subject was then positioned on the treadmill to begin, which consisted of running at 5 miles hr<sup>-1</sup> for 10 min in a thermo-neutral laboratory environment. Each subject participated in both the Control Session (normal running) and the Treatment Session (Groucho running). The order of the two sessions per subject was randomized.

#### Assessments

Heart rate (HR) and oxygen consumption (VO<sub>2</sub>) measurements were averaged across 3, 6, and 9 min of exercise. Heart rate was measured using a Polar Heart Rate Monitor (Polar CIC, Inc). Oxygen consumption was measured using a "breath-by-breath" system (Cardio2 metabolic analyzer, Medical Graphics, St. Paul, MN). The analyzers were calibrated before testing each subject using a 3-L syringe for flow volume across a wide range of flow rates and calibration gases.

Cardiac output (Q) was determined during the 2nd, 30 sec of min 10 using the indirect CO<sub>2</sub> rebreathing procedure [2]. Arterial CO<sub>2</sub> (PaCO<sub>2</sub>) was derived from the end-tidal pulmonary CO<sub>2</sub> (PetCO<sub>2</sub>). Mixed venous pulmonary CO<sub>2</sub> (PvCO<sub>2</sub>) was derived from the CO<sub>2</sub> rebreathing (bag) procedure. Arterial CO<sub>2</sub> and mixed venous contents were calculated from arterial CO<sub>2</sub> tension and PvCO<sub>2</sub>, respectively, using the standard oxygenated CO<sub>2</sub> dissociation curve. The Medical Graphics Cardio2 displayed the CO<sub>2</sub> signal graphically to ensure the PvCO<sub>2</sub> equilibrium. Stroke volume (SV) was computed by dividing Q by HR. Arteriovenous oxygen difference (a-vO<sub>2</sub> diff) was calculated by dividing VO<sub>2</sub> by Q [9]. Mean blood pressure (MAP) was estimated during exercise, using the regression equation [y = .387(HR) + 61.4], as developed by MacDougall and colleagues [6]. This method provides a valid estimation (r = .88) of MAP during exercise and, thus avoids the faulty estimates of SBP and/or diastolic blood pressure when blood pressure is estimated by the auscultatory method. Peripheral vascular resistance (PVR) was calculated by dividing MAP by Q.

#### Data Analysis

Statistical analysis was assessed by a repeated-measures Analysis of Variance. A p value of < 0.05 was considered statistically significant. All values are presented as mean  $\pm$  SD.

## RESULTS

The statistical analysis revealed that Groucho running significantly increased HR and Q, which increased VO<sub>2</sub> (Table I). The increase in metabolic rate was coupled to the increase in exercise Q, which was also achieved by the significant increase in MAP. The significant increase in V<sub>E</sub> was due to the increase in Fb. There were no significant changes in SV, a-vO<sub>2</sub> diff, PVR, and TV.

Parameter	Groucho Running	Normal Running	F-ratio & Prob
<b>VO</b> <sub>2</sub> (L·min <sup>-1</sup> )	2.2 ± 0.41	1.82 ± 0.34	9.37 & 0.03*
HR (beats⋅min <sup>-1</sup> )	166 ± 12	153 ± 16	7.82 & 0.05*
<b>SV</b> (mL)	109 ± 19	101 ± 26	0.03 & 0.87
<b>Q</b> (L·min <sup>-1</sup> )	17.5 ± 2.8	15.2 ± 3	12.38 & 0.02*
<b>a-vO₂ diff</b> (mL·100 mL <sup>-1</sup> )	12.9 ± 2	11.9 ± 1	1.26 & 0.31
MAP (mm Hg)	125 ± 4	120 ± 3	53.99 & 0.00*
<b>PVR</b> (mm Hg·L <sup>-1</sup> ·min <sup>-1</sup> )	7.49 ± 1.1	8.11 ± 0.89	4.53 & 0.09
V <sub>E</sub> (L·min <sup>-1</sup> )	65 ± 12	55 ± 6	6.58 & 0.05*
<b>Fb</b> (breaths⋅min <sup>-1</sup> )	38 ± 6	35 ± 7	14.33 & 0.01*
TV (mL·breath <sup>-1</sup> )	1732 ± 470	1595 ± 440	3.99 & 0.10

#### Table I. Cardiovascular responses to Groucho running (n = 6; Mean ± SD).

\*ANOVA with repeated measures (significant at p < 0.05)

#### DISCUSSION

The results of the present study indicate that 10 min of Groucho-style running has a significant effect on the cardiovascular system. While this type of running has been shown to decrease the shock that is transmitted through the body during the foot strike [8], the subjects' steady-state VO<sub>2</sub> [3,7] was significantly increased (p = 0.03). This finding is in agreement with McMahon and colleagues [1]. Why is this finding important? The less oxygen and energy needed to run at a certain steady-date pace, the longer a person can run. When the same pace requires more oxygen than necessary, then, the exercise will come to a stop that much faster. But, the question is what physiological variables helped to shape the steady-state VO2 response?

By rearrangement of the Fick equation (VO<sub>2</sub> = HR x SV x a-vO<sub>2</sub> diff), it is clear that the increase in VO<sub>2</sub> is due to the subjects' central adjustment (Q) to running with increased knee flexion during the submaximal exercise. The HR response, which is responsible for the increase in Q, is related to the Groucho posture that is more tiring than normal running. In other words, there is a metabolic price for minimizing the trauma of each foot strike. Thus, by forcing the body to use extra muscular activity to maintain the step length for a longer time period, Groucho running decreased the subjects' running economy. The 21% decrease in economy is attributed primarily to the increase in the force of the quadriceps to maintain the knee position during the contact time of running, especially since the cadence of running is not different in normal and Groucho running at the same speed [8].

Our data indicate that with the eccentric increased force in the muscles of the stance-leg during knee flexion, Groucho running had no effect on the extraction of oxygen by the peripheral tissues. This conclusion is warranted since  $a \cdot vO_2$  diff was not changed (p = 0.31). It is also clear that the increase in the rate of energy consumed during the Groucho posture, as measured by the steady-state rate of  $O_2$  consumption, resulted from a central adjustment in Q and not from a peripheral adjustment in tissue extraction. It should also be noted that exercise blood flow to skeletal muscle is coupled to its metabolic rate. During Groucho running, this is achieved by significantly increasing Q and MAP. The latter response is consistent with the fact that it is a major determinant of tissue perfusion, especially given the subjects' non-significant change in PVR. Since afterload is the same for both running conditions, it stands to reason that the average pressure (MAP) exerted by the blood on the arterial wall during a complete cardiac cycle or series of cycles is increased.

Running with the knees in the exaggerated flexed position not only increased the aerobic cost of running, it increased Fb and therefore  $V_E$ . Both aerobic performance measures suggest that Groucho running decreased running economy [4], which is linked a significant increase in respiratory effort. In particular, the significant increase in the  $O_2$  cost of breathing may have engaged a larger percent of the total  $VO_2$  [1]. Potentially, then, the increase in  $V_E$  without an increase in extraction of  $O_2$  (since a- $vO_2$  diff did not change) might be an important reason for the increase in Q to meet the subjects' aerobic demand.

#### CONCLUSION

To our knowledge, the present study is the first to provide cardiovascular data to show in contrast to normal running Groucho-style running results in an increase in exercise HR, which increases the subjects' Q at the same speed. Aside from the fact that Q is increased beyond what it should be, the increase in HR increases the work of the heart (MVO<sub>2</sub>). Our findings also reveal that the central

adjustment in Q is primarily responsible for the increase in steady-state VO<sub>2</sub> and thus, ultimately, is responsible for the decrease in running economy. Since PVR is unchanged with Groucho running (vs. regular running), the significant increase in MAP, as a major determinant of tissue perfusion, is an expected physiologic response to the increase in metabolic rate. The increase in the rate of energy utilization (VO<sub>2</sub>) is related to the increase in V<sub>E</sub>, which is directly related to the increase in RR and the increase in the work of the respiratory system. Lastly, the results confirm that the increase in force required in the antigravity muscles acting to extend the knee had no effect on SV or a-vO<sub>2</sub> diff.

Address for correspondence: Tommy Boone, PhD, MPH, MAM, MBA, Professor, Department of Exercise Physiology, The College of St. Scholastica, Duluth, MN 55811

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