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EFFECTS OF A STANDARDIZED BREAKFAST COMPARED TO FASTING ON THE HEMORHEOLOGIC RESPONSES TO SUBMAXIMAL EXERCISE.

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ABSTRACT.

The effect of breakfast on blood rheology during exercise was studied. 5 subjects (23-27 yr weight 60-84 kg, height 1,72-1,84 m) performed in random order two 25 min submaximal exercise sessions including a final step at 85% of theoretical maximal heart rate during 15 min. This was done fasting and again after eating a 495 kcal breakfast (8,9% proteins, 27,3% lipids; 63.9 % glucids). The rheologic response to exercise was measured at high shear rate with the MT90 viscometer. Changes in whole blood viscosity and hematocrit were similar, but fasting subjects underwent an increase in RBC rigidity (Tk index) while plasma viscosity was higher after breakfast and exhibited a stronger increase during cycling. This breakfast modifies the rheologic response to exercise, by preventing a reduction in RBC deformability and increasing plasma viscosity as well as its rise during cycling.

INTRODUCTION

It has been repeatedly shown that various kinds of acute exercise transiently increase blood viscosity (1,2). For several authors, this physiological hyperviscosity may be a vascular risk factor in some cases (excessive work load, people with cardiovascular diseases) (3,4). Other reports suggest that blood viscosity factors may influence exercise performance, since fitness is known to be statistically associated with increased blood fluidity (4-7).

Key words: Blood viscosity, exercise, hemorheology, erythrocyte deformability, nutrition.

However, blood viscosity is regulated by numerous mechanisms, including metabolic and nutritional influences (8). Therefore, nutrition could be expected to influence hemorheologic changes associated with exercise, with possible effects on muscular performance itself. Two interesting reports have underlined such an influence of nutritional conditions on blood rheology during exercise. Water intake (9-10) has been demonstrated to reduce exercise-induced hyperviscosity by preventing RBC stiffening. Evidence has been given that essential polyunsaturated fatty acids of the omega 3 family increase exercise performance by improving RBC flexibility (11). By contrast, whether blood rheology undergoes the same modifications during exercise in fed and fasting subjects was not, to our knowledge, yet studied. In this paper we investigated the hemorheological adaptation to submaximal exercise after a standardized breakfast compared to fasting.

SUBJECTS AND METHODS

Five healthy volunteers (23-27 yr weight 60-84 kg, height 1,72-1,84 m) performed in random order two 25 min submaximal exercise sessions as indicated below. This was done fasting and again after eating a 495 kcal breakfast (8,9% proteins, 27,3% lipids; 63.9 % glucids). Exercise-tests were performed on a bicycle ergometer (Bodyguard, Jonas Oglaend A.S., N 4301- Sandnes, Norway). Heart rate was continuously monitored with the impulses coming from three electrodes taped to the subject's chest. Indwelling catheters were placed in the antecubital vein 45 min prior the onset of exercise. The exercise test encompassed 10 min increasing work load followed by 15 min at 85% of theoretical maximal heart rate according to the tables of the American Heart Association. Ratings of perceived exertion were measured according to Borg (12). Blood samples for hemorheological measurements (7 ml) were obtained (at times -15, 0, 10, 20, 25 and 35 min) with a large bore needle (Luer adaptor Venoject, set into the catheter) to avoid shear damage to erythrocytes. A vacuum tube was used for blood withdrawal, with potassium EDTA as the anticoagulant. No tourniquet was used for sample drawing in order to minimize venous stasis. Viscometric measurements were performed at high shear rate (1000 s^{-1}) with a falling ball viscometer (MT 90 Medicatest, 37 rue de l'Ermitage F-86280 Saint Benoit) (13). The coefficient of variation of this method ranges between 0.6 and 0.8% (10 repetitive measurements of the same sample). Accuracy of the measurements was regularly controlled with the Carrimed Rheometer 'CS' (Rhéo, 19 rue Ambroise Croizat, 91120 Palaiseau, France). We measured with the MT90 apparent viscosity of whole blood at native hematocrit, plasma viscosity, and blood viscosity at corrected hematocrit (0.45) according to the equation of Quemada (14):

$$\mu b = \mu pl \, . \, (1 - 1/2 \, k.h)^{-2}$$

where μb is blood viscosity, μpl plasma viscosity, h the hematocrit and k a shear dependent intrinsic viscosity of the red cells according to Quemada.

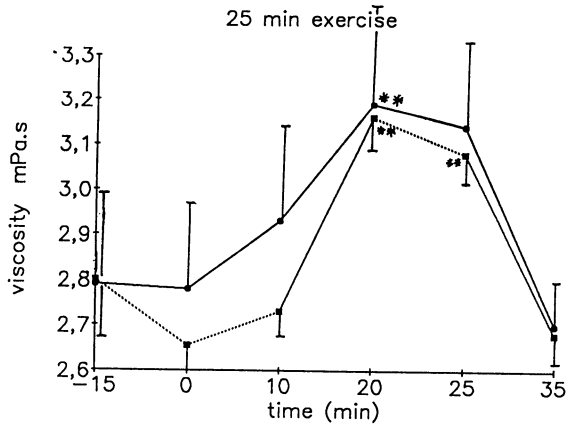

FIG. 1.

Effects of exercise on whole blood viscosity at native hematocrit in fasting subjects (full lines) versus subjects fed with a standardized breakfast (dashed lines). ** p<0.01 vs baseline.

A viscometric index of erythrocyte rigidity (Dintenfass' 'Tk') was calculated:

$$Tk = (\mu r^{0.4} - 1).(\mu r^{0.4}.h)^{-1} \qquad (15)$$

Where μr is relative blood viscosity μb/ μpl.

RESULTS

Power output at the various steps of exercise as well as the ratings of perceived exertion did not differ between fasting and fed sequences. Plasma bicarbonate decrease ($p<0.001$) was the same in both cases. Apparent whole blood viscosity increased in both cases during exercise ($p<0.01$) as shown on fig.1. Blood viscosity corrected for hematocrit (fixed hematocrit 0.45) with Quemada's equation increased in the 20th minute ($p<0.01$) in both situations. Hematocrit changes were the same at rest and after breakfast. Plasma viscosity (fig. 2) in fasting subjects increased in the 10th ($p<0.05$) and the 25th minute ($p<0.01$) and then came back to baseline values at 35 minutes. After breakfast, by contrast, plasma viscosity remained elevated at 25 and 35 minutes ($p<0.01$ and $p<0.05$). RBC rigidity index 'Tk' (fig. 3) increases ($p<0.05$) at the 10th min if subjects are fasting, and is lower ($p<0.05$) at this time in fed subjects. In both situations it is increased at the 20th min ($p<0.01$).

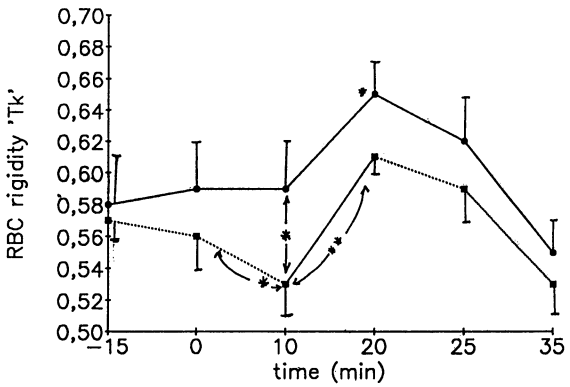

FIG. 2.
Effects of exercise on 'Tk' (index of RBC rigidity) in fasting subjects (full lines) versus subjects fed with a standardized breakfast (dashed lines). * p<0.05; ** p<0.01.

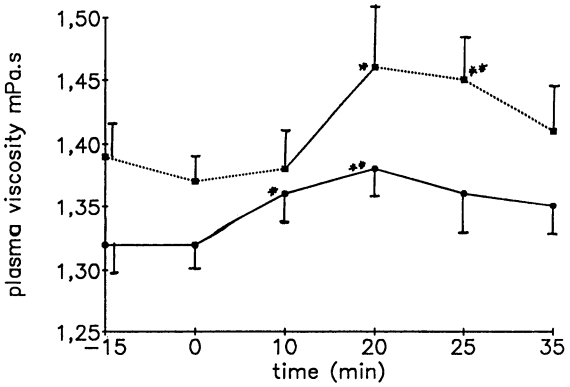

FIG. 3
Effects of exercise on plasma viscosity in fasting subjects (full lines) versus subjects fed with a standardized breakfast (dashed lines). * p<0.05; ** p<0.01 vs baseline.

DISCUSSION

This study showed that whole blood viscosity during submaximal exercise underwent the same modifications in fasting subjects and in subjects fed with this standardized breakfast, but that the effects of the breakfast on plasma viscosity and RBC flexibility are opposite. The breakfast amplifies the increase of the former and partially prevents the decrease of the latter. This meal has been designed to fit with average french habits (16). As in our previous studies on hemorheology during exercise, we measured blood viscosity at high shear rate (1000 s^{-1}). This range of shear rates is not frequently studied in hemorheological studies but has been reported to exist in distal parts of the arterial system (17). We postulate that it is relevant to muscular blood irrigation during exercise. The MT 90 viscometer measures blood viscosity at 1000 s^{-1} with a low coefficient of variation. It has been validated by comparison with the Carri Med Rheometer which works also in this range of shear rates (18).

The breakfast delays and partially prevents the increase in RBC rigidity index 'Tk' during exercise. This effect can be due in part to water intake, according to previous studies (9-10). However, carbohydrate supply may provide an additional explanation. Evidence has been given that carbohydrate feeding delays fatigue (19). Consistent with Ivy (19) we found no difference in total work output, so that the actual performance was not increased by the breakfast. However, if the duration of exercise were longer, differences could be expected, since feeding exerts a beneficial influence upon endurance (19-20). Coyle has demonstrated that carbohydrate feeding delays fatigue and improves endurance in people by preventing blood glucose from dropping which in most of the subjects causes local muscle fatigue during the latter stages of prolonged exercise (20). Energy deprivation may alter RBC metabolism, thus affecting RBC deformability. This point is not fully documented and may require additional studies. Alternatively, fasting may be deleterious for RBC flexibility during exercise by accelerating ketogenesis (21), resulting in increased acidosis, a situation which reduces RBC flexibility (22). However, bicarbonate changes were not different in fasting versus fed subjects. Similarly, lactate levels which have been reported to reduce RBC deformability *in vivo* (23-24) and *in vitro* (25), did not differ between the two situations. Thus, the differences in RBC rigidity modifications may be rather explained by water and / or carbohydrate supply by the breakfast. Since RBC deformability is an important factor of blood distribution in the microcirculation (26-27), such an effect of feeding before exercise may be expected to have some consequences on muscle circulation which require further studies. The actual mechanism for changes in RBC flexibility related to previous feeding remains to be elucidated. The only data which can be found in the literature are the effects of water drinking, which prevent from a fall in RBC deformability during prolonged running (9-10), but a role for carbohydrate feeding cannot be ruled out.

By contrast, the effect of breakfast on plasma viscosity is an increase of this parameter, as well as an amplification of its increase during exercise. Increased plasma viscosity modifies erythrocyte velocity profile in microvessels (28) and impairs tissue perfusion. Plasma viscosity is also negatively correlated with fitness (7, 24, 29-30). This effect of the breakfast on plasma viscosity is probably related to

increased plasma concentration in nutrients coming from the splanchnic circulation. Again, the influence of free fatty acids, fibrinogen, water, and other compounds will need further studies.

On the whole, the breakfast tested here, which represents average french habits, has two opposite effects on two major determinants of blood viscosity during exercise. Thus, whole blood viscosity exhibits the same increase in fed versus fasting conditions. However, at the microcirculatory level, specific properties of cells and suspending medium may become more important than apparent viscosity (26-28), so that it can be hypothesized that the differences between fed and fasting state may have an influence on muscle microvascular circulation.

This study demonstrates also that nutritional conditions prior to exercise should be carefully standardized for studies on hemorheology during muscular activity.

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