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The influence of work intensity on postexercise proteinuria*

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Summary Fifteen men were studied during 100 m, 400 m and 3,000 m runs at maximal speed to determine total urinary protein and albumin excretion rates in relation to different distances of running. Venous blood lactate rose to 7.5 mmol · l^{-1} after the 100 m and 3,000 m events, while reaching 12 mmol · l^{-1} after the 400 m dash. Total urinary protein excretion increased to 330, 1640 and 565 μg · min^{-1} after the 100 m, 400 m and 3,000 m runs respectively, as compared with basal values (70 μg · min^{-1}). In the meantime, albumin excretion increased respectively by 5, 25 and 18 fold of the resting values. The renal clearance of albumin increased to 0.84, 5.62 and 3.35 μl · min^{-1} after the three runs, as compared with a mean value of 0.19 μl · min^{-1} at rest. Exponential relationships ($r=0.85$) were recorded between post-exercise venous lactate and albumin, and total protein excretion. The present work illustrates the major influence of the intensity of exercise (anaerobic glycolytic component), rather than its duration, on the excretion rate of urinary proteins.

Key words: Exercise intensity — Protein — Albumin — Urine

Introduction

The urinary excretion of proteins in normal humans who undergo physical exercise is a well recognized phenomenon (Poortmans 1984). Several mechanisms have been postulated to explain this transient state. Increased permeability of the glomerular membrane and impaired tubular reabsorption of filtered proteins appear to be involved in the enhanced excretion of macromolecules (Poortmans 1984).

Regular post-exercise proteinuria appears in most subjects with prolonged heavy work (Kachadorian and Johnson 1970; McKay and Slater 1962; Poortmans and Jeanloz 1968; Poortmans and Haralambie 1979). However, exhaustive exercises of different types produce a rather large range of proteinurias, from 200 μg to 5,000 μg · min^{-1} (McKay and Slater 1962; Poortmans and Jeanloz 1968; Poortmans and Haralambie 1979). Indeed, Delforge et al. (1969) have shown that the excretion of urinary proteins varies with the intensity of exercise, a greater work load leading to greater proteinuria, a result later confirmed by Kachadorian and Johnson (1970) and Todorovic et al. (1972). Meanwhile these studies have failed to give a clear quantitative answer as to the importance of the factors connected with post-exercise proteinuria. Indeed, the authors above have exercised their subjects by running (Kachadorian and Johnson 1970; Poortmans and Jeanloz 1968; Poortmans and Haralambie 1979), swimming (McKay and Slater 1962) or bicycling (Delforge et al. 1969; Todorovic et al. 1972). On the other hand, there is a lack of information about the relationship between the intensity of exercise and urinary protein excretion registered in the same subjects submitted to a similar type of exercise.

The purpose of the present investigation was to compare the quantitative aspect of total protein and albumin excretion of athletes, each running different distances on an outdoor track, with the concomitant venous forearm lactate levels.

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Table 1. Characteristics and physical performance of the subjects ($n = 15$)

Age (y)		19.5 ± 1.3	
Height (m)		1.79 ± 0.06	
Weight (kg)		71.0 ± 7.6	
$\dot{V}_{O_2max}$ (ml·kg^{-1}·min^{-1})		47.1 ± 3.4	
	100 m run	400 m run	3,000 m run
Time (min:sec)	0:12.4 ± 0:0.1	0:59.3 ± 0:0.4	11:05 ± 0:09
Heart rate at end of exercise (beats·min^{-1})	177 ± 3	186 ± 2	176 ± 3

x̄ ± SEM

Methods

Fifteen male students of physical education took part in this study (Table 1). All subjects were in good health and fully informed of the purpose of the experiment before giving their consent. The exercise sessions were performed on an outdoor track with ambient temperatures ranging from 16 to 20° C. Each subject ran 100 m, 400 m and 3,000 m at his maximal speed. The three races were run on separate days within a two week time scale. Each run was proceded by a 3 hour rest period.

Urine was collected from all subjects before (1 hour collection) and 30 min after the race. Sodium merthiolate was immediately added to the samples (0.01 percent) which thereafter were kept at 4° C. The amidoblack technique of Heremans (1958) was applied for urinary protein determination. Standards were prepared from lyophilized bovine serum albumin (Serva). Aliquots of 10 ml each of the pre- and post-exercise samples were centrifuged at 3,000 g for 10 min. The supernatant fluid was concentrated at 4° C overnight by ultrafiltration under reduced pressure using cellulose dialyzing tubing (Visking) of 8/32 inch inflated diameter (Everall and Wright 1958). Urinary albumin was assayed by the radial single immunodiffusion technique of Mancini et al. (1965). An antiserum against human albumin was purchased (Experimental Medicine — Université de Louvain, Belgium). Standard human serum albumin was obtained from Hoechst Belgium, Brussels.

Blood samples were taken prior to and 5 min following each run. The samples, obtained from an antecubital vein, were collected in heparinized test tubes. An aliquot of blood was immediately transferred to a cold (0° C) 0.6 N perchloric acid solution and measured for lactate by the enzymatic method of Gutman and Wahlefeld (1974). Total protein and albumin in blood were determined by the biuret (O'Brien and Ibbott 1964) and bromocresol green (Doumas et al. 1971) methods respectively. Creatinine was analyzed in blood and urine by the alkaline picrate method (Mark and Zimmer 1967). Urine clearances were calculated from plasma, urine values and urinary output.

The results are expressed as means and standard errors of the means. Statistical significance of the differences were tested by the Student paired t test and non parametric tests (Siegel 1956). The level of statistical significance was set at 95% ($P < 0.05$). Regression methods were used to study the dependence between blood lactate concentration and urinary excretion for all data.

Results

The subjects ran 100 m, 400 m and 3,000 m in the respective mean times of 12.4 s, 59.3 s and 11 min 05 s. Their heart rates reached mean values of 177, 186 and 176 beats · min^{-1} respectively. Blood or venous concentrations and urine excretion rates are summarized in Table 2. The basal values collected before the three events were not statistically different from each other and they fit into the normal values observed in the literature. About 7.5 mmol · l^{-1} lactate was recorded after exercise for the shortest and longest runs while nearly 12 mmol · l^{-1} was obtained for the 400 m. A slight haemoconcentration was recorded according to the statistical increase of total protein, albumin and creatinine. The rate of protein excretion was significantly higher in the post-exercise

Table 2. Blood and venous concentrations and urinary excretions during the three events

Compounds	100 m run Pre	Post	400 m run Pre	Post	3,000 m run Pre	Post
Blood						
lactate (mmol·l^{-1})	0.90 ± 0.04	7.54 ± 0.40*	1.69 ± 0.10	11.99 ± 0.05*	1.13 ± 0.07	7.45 ± 0.60*
Venous						
Protein (g·l^{-1})	75.2 ± 0.1	78.9 ± 0.1*	71.2 ± 0.1	81.0 ± 0.2*	71.8 ± 0.1	75.0 ± 0.1*
Albumin (g·l^{-1})	45.0 ± 0.1	47.6 ± 0.1*	45.5 ± 0.1	52.2 ± 0.1*	45.7 ± 0.1	48.2 ± 0.1*
Creatinine (mg·l^{-1})	9.6 ± 0.3	10.7 ± 0.4*	11.1 ± 0.3	13.1 ± 0.3*	10.4 ± 0.3	12.8 ± 0.3*
Urine						
Protein (μg·min^{-1})	72 ± 21	330 ± 70*	75 ± 10	1640 ± 204*	70 ± 16	565 ± 101*
Albumin (μg·min^{-1})	8.4 ± 0.9	40.5 ± 9.0*	11.8 ± 0.9	296.5 ± 38.4*	8.9 ± 1.3	159.9 ± 24.1*
Creatinine (mg·min^{-1})	1.05 ± 0.11	1.24 ± 0.10	1.34 ± 0.11	1.42 ± 0.11	1.29 ± 0.11	1.34 ± 0.12

x̄ ± SEM
* $P < 0.01$

Table 3. Urinary clearances during the three events

Compounds	100 m run Pre	Post	400 m run Pre	Post	3,000 m run Pre	Post
Albumin ($\mu l \cdot min^{-1}$)	0.19±0.04	0.84±0.19*	0.26±0.03	5.62±0.69*	0.19±0.03	3.35±0.42*
Creatinine ($ml \cdot min^{-1}$)	131±6	117±6	133±5	108±7*	123±9	110±10

$\bar{x}$ ±SEM
* $P<0.01$

than in the pre-exercise samples even after a 100 m run. However, post-exercise proteinuria was most pronounced after the 400 m event.

Whilst creatinine excretion remained stable after the three runs, as compared to resting values, creatinine clearance was reduced by about 17% for the 400 m only (Table 3). Albumin clearance was enhanced by 4, 30 and 18 times the resting values for the 100 m, 400 m and 3,000 m events respectively. These relative increases were not modified by any correction of the corresponding creatinine clearances.

The rates of total protein and albumin excretion were related to venous lactate concentration. To describe this relationship various regression equations were derived, using least squares procedures. The following equations provided the best fits for the total data of the three runs. For total protein excretion: $y=0.03\ e^{0.31x}$ ($r=0,87$, $P<0.001$); for albumin excretion: $y=6.59\ e^{0.30x}$ ($r=0.85$, $P<0.001$) where x is the venous lactate (in $mmol \cdot l^{-1}$) and y represents the urinary excretion expressed in $mg \cdot min^{-1}$ and $\mu g \cdot min^{-1}$ respectively. From these equations it can be observed that both the urinary excretion of total protein and albumin are above the normal physiological range when the venous lactate concentration exceeds a mean value of 5 $mmol \cdot l^{-1}$ (Fig. 1).

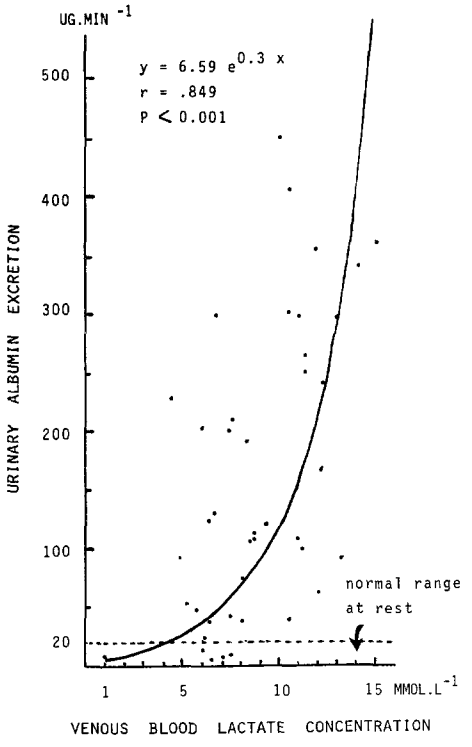

Fig. 1. Relationship between blood lactate *(end of exercise)* and post-exercise albuminuria. The physiological range of albumin excretion at rest is below 20 $\mu g \cdot min^{-1}$ *(dashed line)*

Discussion

A few previous studies have attempted to correlate the rate of protein excretion in urine with the intensity of exercise. Javitt and Miller (1952) reported in three subjects a highly significant correlation between protein excretion and decreased blood pH for two runs on a treadmill — 3 to 5 min and 12 to 22 min of exercise. Govaerts and Delanne (1940), Kachadorian and Johnson (1970), using qualitative methods, were able to observe in five subjects a rough relationship between the intensity of work and the presence of proteins in urine. Hellebrandt et al. (1932) and Todorovic et al. (1972) gave more appropriate evidence by using quantitative data on urinary albumin concentrations during two different types of exercise, on a bicycle and on a treadmill. However, in both studies, the results are still inadequately presented, since they are given as $mg \cdot ml^{-1}$ or per l. Indeed, due to the antidiuretic effect commonly associated with exercise, any data on urine substrate must be expressed by unit of time. Thus no precise argument can be put forward from these aforementioned studies.

On the contrary, the present investigation gives evidence of the importance of work intensity on urinary protein excretion as compared to the duration of exercise. Prolonged exertion does not lead to excessive protein excretion, while heavy

short-term load appears to be the primary element involving post-exercise proteinuria. As the creatinine clearance remained constant or was moderately decreased for the three running events, the changes in glomerular filtration rate do not explain the enhanced excretion of proteins. Therefore, it may be argued that post-exercise proteinuria could be due to increased glomerular membrane permeability and impaired tubular reabsorption, as postulated by previous workers (Poortmans 1984).

A second feature of this tudy was the taking of samples from the same individuals performing the same type of sports event at different intensities and durations. Likewise, blood lactate determination was used as an indirect evidence of work intensity, at least on the glycolytic side, knowing that the three runs lasted between 12 sec and 11 min. We observed for both total protein and albumin an exponential relationship between their urinary excretion rate and the level of blood lactate (Fig. 1). Meanwhile, protein excretion remained within the normal range of a healthy population at rest, as long as the lactate concentration was under about 5 mmol $\cdot$ l^{-1}. This significant relationship does not involve any direct effect between the two parameters. Indeed, Cantone and Cerretelli (1960) failed to observe any increase in protein excretion at rest, while infusing a lactate solution leading to 15 mmol $\cdot$ l^{-1} in blood. Therefore neither increased lactate ion nor decreased pH appears to be related to post-exercise proteinuria. Thus the latter phenomenon seems to be connected with the intensity of exercise, expressed here on the basis of the anaerobic glycolytic component. Von Krull et al. (1984) contradicted previous work on post-exercise proteinuria by claiming that there is no appreciable influence of long term exercise. This observation is quite logical as their exercise, a march of 15 or 25 km, gave a mean pulse rate of around 110—120 beats per min. On the contrary, this work supports our observations on the dependance of work intensity on postexercise proteinuria.

To conclude, the present findings show that the excretion of urinary protein is associated with the intensity of exercise, as expressed by its anaerobic glycolytic component (lactate).

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