ORIGINAL ARTICLE

Relation between serum creatinine and body mass index in elite athletes of different sport disciplines

G Banfi, M Del Fabbro

Br J Sports Med 2006;**40**:675–678. doi: 10.1136/bjsm.2006.026658

Objectives: To document the relation between serum creatinine concentration and body mass index in elite athletes from five different sports, and to study potential differences among athletes performing different sports with different features and requirements.

Methods: Before the start of the competitive season, serum creatinine was measured in 151 elite athletes from five different sports: rugby (n = 44), soccer (n = 27), alpine skiing (n = 34), sailing (n = 22), cycling (n = 24). Pearson's correlation analysis was used to evaluate the relation between serum creatinine and body mass index (BMI). Analysis of variance and unpaired Student's *t* test were used to compare creatinine concentration and BMI in different sport disciplines.

Results: In the whole group of athletes, a positive correlation between serum creatinine and BMI was found ($r = 0.48$, $p<0.001$). Significant differences in creatinine concentration and BMI were found between athletes competing in different sports: their mean (SD) values were respectively 1.31 (0.12) mg/dl and 28.83 (2.41) for rugby players, 1.27 mg/dl (0.10) and 23.10 (1.01) for soccer players, 1.15 (0.11) mg/dl and 25.8 (1.50) for skiers, 1.08 (0.11) mg/dl and 26.93 (2.36) for sailors, and 0.91 (0.07)mg/dl and 21.33 (1.21) for cyclists.

Conclusions: There is a correlation between creatinine concentration and BMI in elite athletes competing in different sports characterised by different kinds of training, competitive season, and involvement of aerobic and anaerobic metabolism. Interpretation of creatinine concentrations in male athletes should consider professional status as well as the specific sport performed. All athletes should be monitored with consecutive creatinine assessments, using as the baseline the concentration determined before the start of training and the competitive season, but taking into consideration the specific sport performed and the BMI until equations that include creatinine and factors that affect its concentration are used.

See end of article for authors' affiliations

Correspondence to:
Mr Banfi, Istituto Galeazzi and University of Milan, Milano 20161, Italy; giuseppebanfi@supereva.it

Accepted 16 May 2006
Published Online First 24 May 2006

The concentration of creatinine in serum has long been the most widely used and commonly accepted measure of renal function in clinical medicine.[1] However, the use of serum creatinine as an indirect marker of glomerular filtration rate has been criticised because it is also affected by age, sex, race, diet, body mass. It was recently suggested that a more precise estimation of glomerular filtration rate can be obtained using specific equations that take into account the influence of the many other factors that potentially affect serum creatinine concentration.[2]

The common reference range used for creatinine in the general population is 0.7–1.3 mg/dl (62–115 μmol/l) for male adults, determined using the Jaffe reaction in automated systems.[3] In a recent report based on a wide population, the range was 0.68–1.13 mg/dl (60–100 μmol/l) for male adults, narrower than the one above.[4] Specific reference values of biochemical variables for sportsmen have never been defined, and those used for the general population, including serum creatinine concentration, are routinely applied to athletes.

In sports medicine, creatinine is widely used for evaluating the general health status of athletes, particularly in events where hydroelectrolytic balance is crucial. Moreover, the urinary concentration of creatinine is used for validating antidoping tests.

Surprisingly, very few papers have been published on creatinine concentrations in athletes, before and/or during competitions, and no data were found on the correlation between creatinine concentration and body mass in elite or recreational athletes.

The reference values commonly used for athletes are those defined for normal, sedentary people. Athletes are usually thought to be physically normal and healthy by definition, but the high training workload and psychophysical stress from competitions may modify their homoeostasis, inducing apparently pathological biochemical and haematological values. Therefore definition of the behaviour of creatinine and its reference ranges in athletes is important to prevent misinterpretation of laboratory data in sportsmen. Furthermore, athletes from different sports disciplines are characterised by different aerobic/anaerobic metabolism, competition season, training, and anthropometric values. In a population of 220 elite male athletes from eight different sports, we found serum creatinine concentrations higher than those measured in age matched sedentary subjects.[5] This finding may be linked to the average higher muscle mass of athletes, because total muscle mass is the most important determinant of the creatine pool size and of creatinine production.[1] In fact, a correlation between creatinine and body mass index (BMI) has been reported in middle aged people in the general population.[6] This should be expected because creatinine originates non-enzymatically from creatine. This correlation has never been reported in elite athletes.

We studied creatinine in elite male athletes from five different sports to evaluate the correlation with BMI among sports and among athletes with different anthropometric characteristics.

MATERIALS AND METHODS

We measured serum creatinine in 151 elite male athletes. They belonged to the national Italian rugby team (n = 44), Italian first division soccer teams (n = 27), America's Cup yacht crew (n = 22), national Italian alpine ski team (n = 34), and ProTour cycling teams (n = 24). Blood was withdrawn before the start of training and the competition

Br J Sports Med: first published as 10.1136/bjsm.2006.026658 on 24 May 2006. Downloaded from http://bjsm.bmj.com/ on 9 October 2018 by guest. Protected by copyright.

season, strictly following preanalytical guidelines.[7] No additional blood was taken for this research, because creatinine is one of the routine variables measured for the evaluation of health status in athletes. Creatinine concentration was measured by the Jaffe reaction in an Aeroset c8000 (Abbott, Chicago, Illinois, USA). The method is calibrated against National Institute of Standards and Technology human serum based standard reference material 909. It should be taken into account that the commutability of this product with native sera has not been established for routine methods.[2] All samples were measured in a single batch after calibration. The reproducibility of the method showed a coefficient of variation of 1.8%. BMI in athletes was calculated as weight (kg)/(height (m))^2.

Pearson's simple correlation analysis was used for statistical evaluation of the association between serum creatinine concentration and BMI. Creatinine concentration and BMI for athletes from different sport disciplines were statistically compared by analysis of variance and unpaired Student's *t* test. We also subdivided subjects according to a threshold BMI value of 25 and used unpaired Student's *t* test to compare creatinine concentrations of sportsmen with BMI<25 and BMI>25.

$p = 0.05$ was considered as the significance threshold. Pearson and Student's *t* test were used after the evaluation of Gaussian distribution of BMI and creatinine concentration in athletes by using the Kolmogorov-Smirnov goodness-of-fit test.

RESULTS

Table 1 reports the main characteristics of the athletes from different sport disciplines.

Figure 1 shows the BMI values as a function of serum creatinine concentration: median values along with 25th and 75th centiles are shown for each sport discipline. A weak positive correlation ($r = 0.48$, $p<0.001$) between creatinine and BMI was observed considering overall values (dotted line). A highly significant difference between sports was detected with analysis of variance for both creatinine and BMI ($p<0.001$). All *t* test comparisons show a significant difference between different sport disciplines (mostly $p<0.01$), except for the comparison between soccer and rugby players for creatinine ($p = 0.12$).

The 65 athletes with a BMI <25 kg/m^2 had a mean (SD) serum creatinine concentration of 1.10 (0.19) mg/dl, whereas the 86 athletes with BMI >25 kg/m^2 had a mean (SD) creatinine concentration of 1.22 (0.14) mg/dl. This difference in creatinine concentration is significant ($p<0.001$).

DISCUSSION

A correlation between creatinine and BMI and a positive association between creatinine and physical exercise have been reported in the general population.[6] The origin of creatinine from creatine may explain this correlation and also the higher concentrations in men than women.[1]

In general, creatinine is not influenced by training and competition,[8 9] even extreme,[10] although some increase (20%) has been reported in endurance and ultraendurance performances.[11 12]

Creatine supplementation was not used in the teams we studied. Although personal uncontrolled use of creatine by single athletes cannot be excluded, the large number of subjects recruited from five different sports should minimise the possible influence of creatine use. Furthermore, creatine supplementation has a minimal effect on creatinine concentrations and renal function in young healthy adults, as reported in a review of the literature from 1966 to 2004.[13] Creatinine is therefore a fairly stable variable in athletes, but its concentration may differ from those of sedentary people and sometimes among sports, and also at different stages of the competitive season in the same athletes.[5 14]

Differences between sports disciplines can be linked to BMI. We found a correlation between creatinine and BMI in the overall group of athletes studied. The different sports are characterised by different kinds of training, competitive seasons, and involvement of aerobic and anaerobic metabolism, and the correlation was associated with the peculiar status of professional sport.

The correlation was present in the whole group, but was weak in the separate sport groups, probably because of the relatively limited number of subjects. There are no specific data in the literature, but an evaluation during an ultramarathon cycling race showed an increase in creatinine when body weight decreased.[11] We studied the athletes before the start of the training season, but it is possible that the behaviour of creatinine during the competitive season was different—for example, lower creatinine concentrations were found in cyclists and nordic skiers during the competitive season compared with those of sedentary subjects. Furthermore, slightly lower creatinine concentrations were found in 50 professional road cyclists than in 35 sedentary healthy people (82 (12) *v* 87 (9) µmol/l (0.93 (0.14) *v* 0.98 (0.10) mg/dl), $p = 0.044$).[14 15] The creatinine concentrations that we found in the cyclists were close to those reported in another study of 80 cyclists: 0.84–0.98 *v* 0.72–0.95 mg/dl respectively. It could be hypothesised that the range of variability may change according to the phase of the competitive season, and the different ranges observed in these two studies may be due to the fact that the two groups were examined during different periods of the season. Another explanation may be the different sample size (24 *v* 80 subjects).[14]

Interpretation of creatinine concentrations in sportsmen should take into consideration the specific sport of the athlete. In some aerobic sports—for example, cycling—the BMI values are fairly homogeneous, whereas in others—for example, sailing, rugby—the values are heterogeneous. In the

Table 1 Characteristics of athletes from different sport disciplines

	Rugby	Soccer	Alpine ski	Sailing	Cycling
Number	44	27	34	22	24
Age (years)	24 (3.8)	25 (4.0)	22.5 (4.5)	28.5 (6.5)	26 (4.1)
Training (hours/day)	3.5 (1.5)	3.3 (1.2)	3.7 (0.5)	2.0 (0.5)	5.2 (0.2)
Height (cm)	185.6 (7.5)	181.0 (4.0)	179.7 (5.2)	184.0 (6.2)	178.5 (6.1)
Body weight (kg)	99.1 (10.8)	76.4 (5.9)	83.3 (6.6)	91.6 (11.7)	68.0 (5.6)
Serum creatinine (mg/dl)	1.31 (0.12)	1.27 (0.10)	1.15 (0.11)	1.08 (0.11)	0.91 (0.07)
BMI (kg/m^2)	28.83 (2.41)	23.10 (1.01)	25.78 (1.71)	26.93 (2.36)	21.33 (1.21)

Values are mean (SD).
BMI, Body mass index.

Br J Sports Med: first published as 10.1136/bjsm.2006.026658 on 24 May 2006. Downloaded from http://bjsm.bmj.com/ on 9 October 2018 by guest. Protected by copyright.

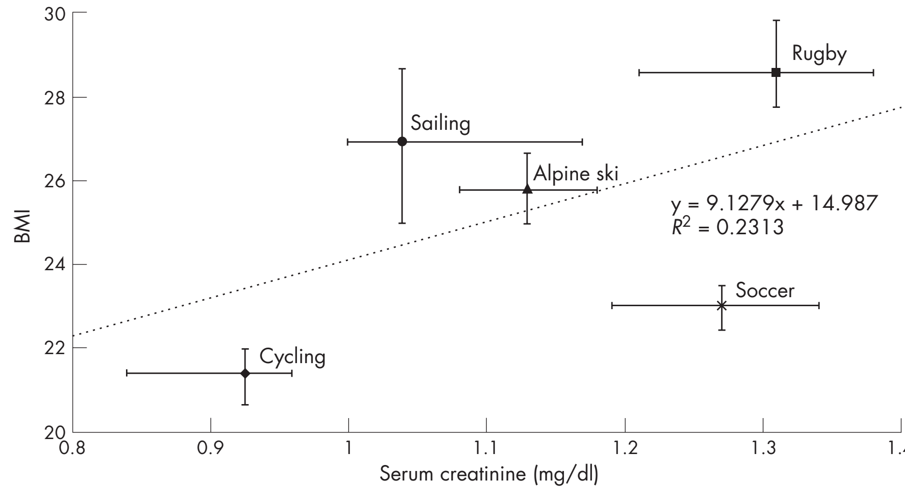

Figure 1 Correlation between serum creatinine and body mass index (BMI) in the different sports. Median creatinine concentration, median BMI, and the corresponding 25–75% are illustrated. Creatinine concentration is given as mg/dl; this can be converted into µmol/l by multiplying by 88.4.[3]

What is already known on this topic

- There is considered to be a relation between body mass and creatinine concentration in the general population, but it has not been specifically reported for top level athletes, who have higher creatinine concentrations than sedentary people

What this study adds

- The correlation between body mass and creatinine concentration is confirmed in top level athletes from five different sports characterised by different training, aerobic/anaerobic metabolism, and competitive season
- Interpretation of the creatinine concentration should take into consideration the status of the professional athlete and the specific sport performed

latter sports, there are athletes with quite different anthropometric characteristics, often linked to their role. In rugby, for example, the BMI of forwards is generally higher than that of backs; also in soccer, goalkeepers tend to have a higher BMI than other players.

The correlation between creatinine and BMI is not necessarily only connected with muscle mass. Lean mass is not crucial for defining creatinine concentration, as reported in broad populations.[16] In our study, the cyclists, typically characterised by low fat percentages, have the lowest creatinine concentrations, whereas rugby players, with relatively high body fat,[17] have the highest creatinine concentrations, confirming previous findings in the general population.[18] This must mean that the homoeostatic values of creatinine are related not only to body size, but also to other physiological mechanisms, such as the effect of increasing volume of distribution: it is known that total body water is closely related to body mass.[19]

When serum creatinine concentration is used to estimate glomerular filtration rate, the use of recently developed equations is recommended, such as the one described for the modification of diet in renal disease (MDRD), which includes the creatinine concentration and factors that influence it. The use of the MDRD equation should also be encouraged in sport medicine, because it is not influenced by body mass.[2]

The use of reference ranges determined for the general population should not be recommended in sports medicine, to prevent misinterpretation of data and unnecessary further investigation. This does not necessarily imply that specific reference ranges should be calculated for athletes: the individuality index (ratio between intraindividual and inter-individual variability) of creatinine in athletes is 0.33,[20] which is lower than the value of 0.60 universally considered the threshold for classifying a reference range useful for a population. We recommend that every athlete should be monitored with consecutive creatinine assessments, using as the baseline the concentration determined before the start of training and competition, but taking into consideration the sport performed and the BMI.

Authors' affiliations

G Banfi, M Del Fabbro, Istituto Galeazzi and University of Milan, Milan, Italy

Competing interests: none declared

REFERENCES

1 **Perrone RD**, Madias NE, Levey AS. Serum creatinine as an index of renal function: new insights into old concepts. *Clin Chem* 1992;**38**:1933–53.
2 **Myers GL**, Miller WG, Coresh J, *et al.* Recommendations for improving serum creatinine measurement: a report from the Laboratory Working Group of the National Kidney Disease Education Program. *Clin Chem* 2006;**52**:5–18.
3 **Burtis CA**, Ashwood ER, eds. *Tietz textbook of clinical chemistry*, 2nd ed. Philadelphia: Saunders, 1994:2184.
4 **Rustad P**, Felding P, Franzson L, *et al.* The Nordic Reference Interval Project 2000: recommended reference intervals for 25 common biochemical properties. *Scand J Clin Lab Invest* 2004;**64**:271–84.
5 **Banfi G**, Del Fabbro M. Serum creatinine values in elite athletes competing in 8 different sports: comparison with sedentary people. *Clin Chem* 2006;**52**:330–1.
6 **Vikse BE**, Vollset SE, Tell GS, *et al.* Distribution and determinants of serum creatinine in the general population: the Hordaland Health Study. *Scand J Clin Lab Invest* 2004;**64**:709–22.
7 **Banfi G**, Dolci A. Preanalytical phase of sport biochemistry and haematology. *J Sports Med Phys Fitness* 2003;**43**:223–30.
8 **Gerth J**, Ott U, Funfstuck R, *et al.* The effects of prolonged physical exercise on renal function, electrolyte balance and muscle cell breakdown. *Clin Nephrol* 2002;**57**:425–31.
9 **Saengsirisuwan V**, Phadungkij S, Pholpramool C. Renal and liver functions and muscle injuries during training and after competition in Thai boxers. *Br J Sports Med* 1998;**32**:304–8.

Br J Sports Med: first published as 10.1136/bjsm.2006.026658 on 24 May 2006. Downloaded from http://bjsm.bmj.com/ on 9 October 2018 by guest. Protected by copyright.

10 **Fallon KE**, Sivyer G, Sivyer K, *et al*. The biochemistry of runners in a 1600 km ultramarathon. *Br J Sports Med* 1999;**33**:264–9.
11 **Neumayr G**, Pfister R, Hoertnagl H, *et al*. The effect of marathon cycling on renal function. *Int J Sports Med* 2003;**24**:131–7.
12 **Kratz A**, Lewandrowski KB, Siegel AJ, *et al*. Effect of marathon running on hematologic and biochemical laboratory parameters, including cardiac markers. *Am J Clin Pathol* 2002;**118**:856–63.
13 **Pline KA**, Smith CL. The effect of creatine intake on renal function. *Ann Pharmacother* 2005;**39**:1093–6.
14 **Lippi G**, Brocco G, Franchini M, *et al*. Comparison of serum creatinine, uric acid, albumin and glucose in male professional endurance athletes compared with healthy controls. *Clin Chem Lab Med* 2004;**42**:644–7.
15 **Lippi G**, Salvagno GL, Montagnana M, *et al*. Influence of physical exercise and relationship with biochemical variables of NT-pro-brain natriuretic peptide and ischemia modified albumin. *Clin Chim Acta* 2006;**367**:175–80.
16 **Swaminathan R**, Major P, Snieder H, *et al*. Serum creatinine and fat-free mass (lean body mass). *Clin Chem* 2000;**46**:1695–6.
17 **Nicholas CW**. Anthropometric and physiological characteristics of rugby union football players. *Sports Med* 1997;**6**:375–96.
18 **Lamb EJ**, Tomson CRV, Roderick PJ. Estimating kidney function in adults using formulae. *Ann Clin Biochem* 2005;**42**:321–45.
19 **Swaminathan R**, Ho CS, Chu LM, *et al*. Relation between plasma creatinine and body size. *Clin Chem* 1986;**32**:371–3.
20 **Fraser CG**. *Biological variation: from principles to practice*. Washington, DC: AACC Press, 2001.

COMMENTARY

Because of substantial physical and metabolic adaptations, analysis of biochemical data in elite athletes requires caution. This article deals with an intriguing issue in sport medicine: the identification and appropriate implementation of reference ranges of laboratory tests in athletes. This is a much underestimated problem when evaluating athletes for both antidoping and health purposes. Thus this article represents a valuable contribution, showing that values from laboratory tests that lie outside conventional reference limits calculated using values from sedentary populations may reflect physiological adaptations to regular and demanding physical aerobic activity rather than resulting from pathologies or unfair practices.

G Lippi
Istituto di Chimica e Microscopia Clinica, Universita degli Studi di Verona, Verona, Italy; ulippi@tin.it

Br J Sports Med: first published as 10.1136/bjsm.2006.026658 on 24 May 2006. Downloaded from http://bjsm.bmj.com/ on 9 October 2018 by guest. Protected by copyright.