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# The effects of long lasting physical exercise and training on kidneys functions

## Abstract

During long lasting physical exercise and physical training, a large number of changes occur in the human body. The body homeostasis is disturbed, and observed changes include kidney function. The most common observed symptom is a decrease in the amount of urine excreted due to an increase in the secondary absorption of water during exercise.

During long lasting physical exercise the filtration in the glomeruli is impaired, and thus the composition of urine is changing. Differences in the amount of minerals excreted are noted, as a result of water loss, and urine osmolarity increases. Those changes are depend largely on the type of undertaken physical activity, its duration, as well as the individual predisposition of the examined physical active human. Therefore, in individual studies, the results differ significantly, and it is impossible to draw unequivocal conclusions.

**Keywords:** long lasting physical exercise, training, health, kidney

## Introduction

"Physical activity can replace almost any drug, but no drug can replace movement", this famous quote by Wojciech Oczko, who was the court doctor of Polish kings in the 16th century, is often quoted by people who intensively promote physical activity. It shows that there is nothing more beneficial for the human body than physical activity. Nowadays there is a fashion for "healthy lifestyle". It is common belief that everyone can run. Thus, according to the above statements, physical activity is a simple path to health.

Nowadays one of the most common types of physical activity is marathons, triathlons and longtime running. This very specific type of activity modulates body functions, not always in the healthy way. Some observed changes can be devastating for human health and homeostasis. In this article we try to show effect of long lasting physical activity on human health and kidneys functions.

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## Physical activity – glomerular filtration

Body functions and regulation always changes during physical activity and training. The most common reaction to long-term physical activity is a decrease in the amount of urine production (diuresis). During prolonged work, diuresis may drop to 0.5 ml per minute, this condition does not disappear even for several hours after the end of exercise. The reason for this phenomenon is the increase in water resorption in the tubules, while reducing glomerular filtration. A decrease in renal blood flow is responsible for reduced glomerular filtration (Smoleński, 2001).

This is because during exercise, more blood is directed to structures that are directly involved in the body's work (e.g. muscles or lungs). There are contractions of the drainage and supply arterioles in the glomerulus due to an increase in the amount of angiotensin and noradrenaline as well as the reaction of the sympathetic system (Smoleński, 2001).

Glomerular filtration is controlled by renal autoregulation (contraction and relaxation of the draining arteriole, depending on the body's needs). Thanks to this mechanism, during the decrease in renal blood flow, the qualitative filtration fraction (glomerular filtration rate to effective renal blood flow) increases from 15 to 25%.

When physical exertion reaches high intensity, glomerular filtration ultimately decreases. With physical effort, such as long-distance running or cross-country skiing, This parameter can decrease to 39%, with a simultaneous decrease in renal blood flow by 50% (Smoleński, 2001).

During exercise, changes in the composition of urine are observed. In a state of extreme dehydration, urine osmolarity may increase to 1200 mOsm / kg $H_2O$. During very exhausting physical exertions, it can be even lower. This is due to a decrease in renal tubular function. A factor that increases the risk of this ailment is that the player receives a large amount of water in a very short time (Smoleński, 2001).

There are also changes in the specific gravity of urine, which increases as a result of exhaustion and increase in water loss. The following changes were noted in the study by Jablan (2017). Immediately after exercise, the osmolarity was 1.03 ± 0.006, to change slightly after 1.0 hours to 1.03 ± 0.007. After 24 hours, value return to 1.02 ± 0.008. Return to baseline was the result of replenishing of the fluids lost during exercise and post-exercise regeneration of the body.

## Physical activity – urine changes

Exercise affects the amount of minerals excreted in the urine. To increase the level of minerals and trace elements in the urine, immediately after exercise, can contribute to increased blood flow and changes in renal function that are characteristic of endurance exercise (2017, Jablan). Such changes in the urinary excretion of individual minerals (during the ultramarathon course) are presented in Table 1.

**Tab. 1.** Changes in the excretion of individual elements in urine of mountain ultramarathon runners (Jablan, 2017)

| Parameters | Output values | Immediately after the run | 12 hours after the run | 24 hours after the run |
|---|---|---|---|---|
| **Se (µg/L)** | 4,04±10,20 | 82,59±136,44 | 47,81±76,53 | 26,54±43,12 |
| **Zn (µg/L)** | 263,19±295,74 | 2000,17±2661,94 | 1423,06±2219,65 | 748,50±888,50 |
| **Mn (µg/L)** | 208,41±237,67 | 2797,23±3756,05 | 814,59±1743,71 | 892,00±2005,85 |
| **Cu** (µg/L) | 15,00±13,59 | 82,15±122,96 | 70,00±120,63 | 68,96±99,13 |
| **Fe (µg/L)** | 46,75±40,62 | 167,30±186,70 | 161,38 ±116,49 | 108,63 ±74,95 |
| **Co (µg/L)** | 46,80±39,09 | 404,05 ±409,64 | 405,95±718,87 | 392,44±712,88 |
| **Ca (mg/L)** | 80,85±75,84 | 272,48±460,89 | 366,28±587,18 | 355,52±438,95 |
| **P (mg/L)** | 234,49±321,56 | 817,35±957,59 | 1801,15±3082,90 | 1757,67±2370,58 |
| **K (mg/L)** | 831,49±609,75 | 8937,42±1265,17 | 4223,86±6882,23 | 4371,71±7408,22 |
| **Na (mg/L)** | 579,8±438,12 | 1489,46±2513,78 | 962,36±1193,44 | 1595,26 ±1529,40 |

During prolonged exercise, potassium excretion increases, due to increased level of blood aldosterone, as well as in the case of high acidification of the body during exercise. The excretion of ammonia, sulfates and chlorides is reduced (Smoleński, 2001).

A significant increase in the level of minerals, i.e. calcium, phosphorus, potassium and sodium in the urine of participants of mountain ultramarathon was observed immediately after the run, with a constant increase in the concentration of calcium and phosphorus, a slow decrease in the concentration of potassium and a variable level of calcium (Table 1), after the period of 24. hours (Jablan, 2017).

These minerals play an important role in muscle contraction and nerve transmission, and are involved in maintaining normal osmotic pressure, water regulation and acid-base balance. In addition, they build structures such as bones, membranes, nucleic acids, nucleotides and proteins. In this regard, their increase level during the regeneration period, can be explained by remedial processes (Speich, 2001, Williams, 2005).

The proper concentration of magnesium in the human body is necessary for the functioning of the muscles and vascular system. Magnesium deficiency leads to a skeletal muscle spasms, and in extreme cases arrhythmia. Shortage of this element is to a large extent exposed to athletes practicing long-term efforts, where there are significant changes in the amount of excreted magnesium in the urine (Williams, 2005).

In studies conducted by Buchman (2013), the following values were noted in samples taken before run, where the average amount of magnesium in urine was 34.02 ± 8.64 ppm. After the run, these values dropped significantly, to 21.80 ± 12.24 ppm. It is speculated that a decrease in the concentration of excreted magnesium is associated with an increase of the body's need for this element, especially in the area of skeletal muscle (Buchman, 2013).

Zinc as a component of many enzymes in the human body has an impact on basic life processes. That is why it is so important to kept its level at the normal limits. During the aforementioned studies (Buchman, 2013), the level of zinc excreted in the urine was measured. In the first uptake, the zinc value was 0.33 ± 0.21 ppm, while after the run its slight decreased to 0.30 ± 0.25 ppm. The reported zinc losses seem insufficient to cause any decrease in total zinc that could affect the skeletal system and muscle performance (Buchman, 2013). During long-term efforts, the plasma concentration of zinc does not change, and in some cases its increase (Montain, 2007), so there is no correlation between the level of serum zinc and its excretion in urine. However, a decrease in the excretion of zinc in the sweat production process is observed. The level of sweat zinc decreases significantly during the first hour after starting physical exercise, which leads to the statement that the body is trying to reduce its loss. However, in studies conducted by Jablan (2017), an increase in the level of trace elements (Table 1) in the antioxidant defense system (Se, Zn and Mn) was observed, which increased immediately after the race and returned to baseline after the observation period (24 hours). This could reflect a higher synthesis of antioxidant enzymes as an adaptive response to oxidative stress that occurred during endurance activity (Jablan, 2017).

With very intense physical activity such as the marathon run, iron-containing compounds are excreted in the urine. This is an extremely dangerous situation because the iron released from hemoglobin affects the renal tubules. Iron precipitation occurs at high exercise intensity, during which the breakdown of muscle tissue is observed, which, together with the simultaneous production of myoglobin in the blood, has a toxic effect on the kidneys.

Athletes subjecting their body to such a heavy load are significantly exposed to increased iron loss, which can lead to a number of disorders such as headaches, fatigue and apathy. In some cases, a significant loss of iron can lead to anemia, in which there is not enough blood erythrocytes, which in turn leads to hypoxia. In addition, it has been diagnosed that in cases of athletes iron is much less well absorbed than in non-training population. In training people, iron is lost in the process of cooling the body when sweat is produced, as well as through the urinary system (Górski, 2001).

During prolonged, intensive work, erythrocytes may enter the urine, which should not be in properly balanced urine. Red blood cells in the blood are destroyed during prolonged exercise, in the process of post-workout haemolysis (Smoleński, 2001).

After long-term exercise (53 km run), an increase in urine iron was observed, which persisted throughout the entire observation period (24 hours). Iron (along with copper) as a functional component of hemoglobin, myoglobin, cytochromes, is involved in the transport and metabolism of oxygen for energy production in aerobic processes. In addition, both iron and copper participate in the process of antioxidant defense, and also act as pro-oxidants. To have a full picture of the changes taking place, the copper concentration was also measured. Its urine concentration remained high compared to baseline, while iron levels (although above normal) tended to decrease (Jablan, 2017).

Cobalt helps in the absorption of iron, which in turn leads to increased body efficiency. At the same time, cobalt is a factor regulating the sympathetic nervous system, normalizes blood pressure and is important for metabolism because it is involved in the activation of enzymes. The amount of cobalt in urine increases under prolonged effort. During the study of Svyatova (2013), it was noted that its concentration in urine increased tenfold after a long distance run and, as in the case of copper concentration, its level remained increased throughout the entire observation period. Comparable to iron and copper, higher cobalt levels during observation may be associated with body regeneration. The results differ slightly. It can be seen that the measurements did not show a change in the level of plasma cobalt (Soria, 2016) during intense exercise in professional athletes. There is also no unambiguous information that the increase in cobalt concentration in the urine was the result of impaired renal function during prolonged exercise.

Chromium is a mineral that is essential for the body. Affects fat and glucose metabolism. It supports the function of insulin, which can be important during prolonged exercise. One of the works determining the level of chromium during a run over a distance of 130 kilometers was Buchman's study (2013), where the level of chromium in both urine and serum was determined.

The discrepancies between the first measurement taken before the run and the test samples are very small. Before exercise, the serum zinc level was 0.9 ppm, whereas immediately after the run 0.96 ppm. The level of zinc in urine before exercise was 0.33 ppm, while after running 0.30 ppm. Such small differences seem to be statistically insignificant and it can be argued that prolonged exercise does not affect the level of chromium in urine excretion. Other results were presented by Arakawa (2016). He used the measurement of serum chromium as an indicator of renal function. During his research, the increase in excreted chromium was already so large that, according to the author, the observed changes occurring in the urine suggest that the glomerular filtrate was temporarily disturbed as a result of muscle damage and large protein waste getting into the kidneys (Arakawa, 2016).

Considering the comparison of the results from the above studies (Buchman, 2013, Svyatova, 2013, Arakawa, 2016, Soria, 2016, Jablan, 2017) it can be concluded that the level of excretion of minerals and trace elements in urine depends largely on the type of performed sport, its duration and level of training of the participants, as well as individual characteristics of the body, which in turn leads to heterogeneous results.

Blood urea is the final product of the breakdown of protein as well as muscle structures. The level of protein products can be naturally elevated due to muscle injuries during prolonged efforts. In studies conducted by Arakawe (2016), it was noted that the level of urea in urine was slightly increased and after the regeneration period, remained in the range slightly abnormal. Therefore, it can be concluded that the function of renal filtration of runners was preserved during and after a long endurance race (Arakawa, 2016).

Proteinuria is a very common symptom accompanying to long-lasting physical activity.. The severity of this phenomenon is an individual feature. Increases in the glomerular basement membrane are responsible for the presence of protein in urine excreted. Usually albumin is present in the urine, and in some cases transferrin and globulin can also be also observed (Smoleński, 2001). Studies by Mohamadzadeh (2016) have shown that the level of urine protein after exercise compared to the values before training are significantly increased. These values are observed in up to 70-80% of athletes surveyed. However, in other studies (Jablan, 2017), conducted on competitors of the mountain ultramarathon race, the tests excluded the presence of protein in the urine before the start, in order to record the value of 0.05 ± 0.112 g/L in 14% of the competitors, immediately after exercise. 0.03 ± 0.095 g / L in 10% of competitors 12 hours after finishing the race. Very high levels of protein in the urine were observed, which could indicate significant kidney damage. However, after a day, the body returned to normal, no protein was present in case of any players. Comparing both studies, it cannot be unequivocally determined how frequent proteinuria is after intense exercise. Differences in results may occur due to the nature of the effort made by the subjects (Mohamadzadeh, 2016).

Professional basketball players took part in the Mohamadzadeh research, the measurement was made after a long-lasting exercise, however it was significantly different from the ultramarathon run. Basketball training is characterized by speed endurance, there is a lot of changes in the pace of the run, during work additional muscle groups are activated. In the ultramarathon race, the effort is more uniform. Hence, it can be concluded that a shorter effort of higher intensity leads to a greater increase in protein in the urine than a prolonged effort of a uniform nature. Hematuria is a common symptom occurring during long-term efforts. The appearance of blood in the urine may be a consequence of post-workout haemolysis, but also the effect of mechanical damage to the glomerulus and may occur due to microscopic bleeding due to bladder movement during running. During running competitions over a distance of 100 kilometers, measurements were made for the presence of occult blood in the urine. The results obtained are presented in Table 2 (Yu-Hui, 2015).

**Tab. 2.** Occurrence of hematuria in competitors in a 100 km run

| **UOB** | **Before exercise** | **After exercise** | | **Before exercise / after exercise** | |
|---|---|---|---|---|---|
| | **I collection** | **II collection** | **III collection** | **II collection** | **III collection** |
| − | 25 | 8 | 19 | 0,002 | 0,012 |
| −/+ | 0 | 2 | 0 | | |
| + | 0 | 2 | 1 | | |
| ++ | 0 | 2 | 3 | | |
| +++ | 0 | 11 | 2 | | |

Creatinine is another compound that is released in the urine. It is a chemical compound formed in the process of metabolism, which takes place mainly in skeletal muscles. It is produced by the breakdown of creatine, which is one of the energy carriers in the human body. Creatinine is filtered through the kidneys and its urine value should be constant. During long-term efforts, the amount of excretion of this compound with urine changes. Increased urine creatinine has been observed, which may be evidence of renal failure and glomerular filtration disorder, but in most cases increased physical activity is responsible for increased urine levels. People who practice marathon runs have a significant increase in creatinine immediately after the run. The increased norm is maintained for 2-7 days for marathon runners and 1-2 days for runners starting at half of this distance (Bekos, 2016).

Similar results were presented by Jablan (2017). To provide a full picture of the processes taking place, three abstractions were made to determine whether, and how quickly, after the competition, the body will return to homeostasis. Studies have shown a significant increase in creatinine levels that occurred immediately after the race. During the observation (24 hours after the run), it was noted that the creatinine value slowly decreased and returned near the baseline value. In the control study (before exercise), the urine creatinine value was 20.92 ± 11.098 mmol / L. Immediately after exercise, the concentration increased significantly, being 40.20 ± 18.459 mmol / L, to reach 32.58 ± 15.400 mmol / L after 12 hours. Finally, after 24 hours, this value was 24.59 ± 11.615 mmol / L, very close to the initial value. Thanks to the collected data, it can be assumed that during exercise, kidney damage occurred, which, however, resolved spontaneously after a period of rest and recovery.

Maintaining acid-base balance is necessary for the proper functioning of the body. During prolonged physical exertion, the body is acidified by increasing the concentration of lactates in muscles and plasma (Smoleński, 2010), which can also be seen as a change in urine pH. Research conducted by Jablan (2017) was to provide information on how much the acid-base balance of the body was disturbed, and at what time the body will return to homeostasis. Before the run, urine pH was 5.9 ± 0.71. Immediately after exercise, this value increased to 6.0 ± 0.67, while after a day, the pH returned to the value before the run and was 5.9 ± 0.71. Assuming that the normative value for urine is pH 7.4 (Smoleński, 2001), it can be observed that the competitors during the first intake were already characterized by significant acidification of the body. This condition may have been caused by pre-start overtraining. On the other hand, the values of individual abstractions do not differ significantly from each other, so the unequivocal statement that prolonged physical effort affects the balance-base cannot be confirmed.

## Summary

Considering all the data presented in this paper, it can be unequivocally concluded that prolonged exercise is not beneficial to the human body. To protect yourself against the adverse effects of this type of work that your body does, you need to adapt gradually.

One of the main factors protecting kidneys from dysfunctions is adequate hydration during exercise. Too little water impairs the work of the whole body, for the kidneys this situation is extremely dangerous, because due to insufficient water, kidney function may be impaired, renal tubular function may deteriorate, which may lead to acute kidney failure. Changes occurring as a result of long-term efforts are to a large extent individual characteristics of the players. Therefore, it is extremely important for athletes practicing this type of physical activity to undergo periodic check-ups to check the level of fitness and fitness of the body. A very good and easy way to control these parameters is a simple urine tests.

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