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An attempt to determine early and late spontaneous restitution after endurance effort in a man in his sixties based on selected blood indicators. A case study

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Summary
Introduction.

Rest, in its physiological understanding, is a dynamically changeable state which immediately follows the end of physical or mental exercise, or a decrease in their intensity. In such a state, assimilatory processes dominate over dissimilatory processes. Also metabolic by-products are being erased and there occurs the normalization of various bodily processes. What is equally important is the time period after which one finds oneself in an optimal state to undertake the next physical effort – the time of early and late restitution – understood here as physiological restoration of individual rest homeostasis after physical effort without the use of any means enhancing this natural process. The aim of the study is to determine, based on selected blood indicators, the time occurrence of the early and late spontaneous restitution after endurance effort in a man in his sixties.

Material and methods. The studied individual who lives a healthy life-style subjected himself to the markings of some selected blood indicators after endurance effort during the process of spontaneous restitution: HCT, MCHC, MCH, PLT, MCV, MPV, PCT, RDW, PDW, pH.

Results. Positive results were observed in most of the measured blood features. However, their configuration during 5-day measurement cycle varied. The most positive changes occurred in the following features: HCT percentage, MCH, MCHC, RDW, pH.

Conclusion. (1) The process of early and late restitution after endurance effort in a 61year-old man runs accordingly to the generally accepted time intervals. The period of early restitution lasts 3-4 hours, and then the next 41 hours. (2) In order to more accurately determine time periods of the early and late restitution the research on a relatively larger population of varied sex and age is required; such a research would have to be conducted both before and after the physical efforts and it would have to engage various motoric functions of the studied individuals.

Introduction

The phenomena such as increased oxygen absorption, spontaneous post-effort restitution and supercompensation are well known among young, physically active people. However, there are significant differences between homeostasis of children, young people in their 20/30s and people in their 60/70s. By the same token, also post-effort restitution differs. Theory of recreational physical activity of the people in their sixties is well described. In subject literature, however, there are relatively few publications presenting spontaneous restitution process in elderly people, and even less has been written on the specific effects of broadly defined process of biological restitution. Most often physical endurance effort is recommended that, if realized by the elderly people, improve the functions of oxidative enzymes. A & A Jaskólski [1] indicated that around 8% of IIX type fibers acquire the features of type IIA, and that there increases the surface of I and II A fibers. Hence, systematically performed endurance work enables one to maintain, well into one's old age, high activity of oxidative enzymes as well as unchanged capillarization. The area of these changes depends on the mentioned regularity, capacity, volume and intensity of the realized endurance work. Nevertheless, after performed work, the only way of coming back to the state from before physical effort is rest. Rest is a time interval between subsequent periods of activity. In physiological understanding, rest is a dynamically changeable state taking place directly after the end or decrease in intensity of physical or mental work. During rest period, there occurs domination of assimilatory over dissimilatory processes. Also the by-products of metabolism are being removed from the body and metabolism itself decreases and normalizes. It is one of many internal bodily restitution mechanisms. In its dynamics, one may observe some regularities: (1) uneven course of fast phase, lasting 2-20 minutes, and slow phase, lasting 2-3 days, (2) phase character, embracing early phase, lasting a few minutes, and late phase, lasting a few days, (3) heterochrony and (4) non-simultaneity [2]. The time period after which optimal conditions for undertaking another physical work are created, time of early and late restitution – here understood as restoration of individual rest homeostasis after effort without any substances enhancing this natural process – is by no means less important [3].

The aim of the present work is to determine, based on selected blood indicators, time occurrence of early and late spontaneous restitution after endurance work in a man in his sixties.

1. Materials

The studied individual is 61 years-old, weights 83,3 kg and measures 172 cm. His BMI is 28,2; total fat 24,4 and internal fat 14; muscle percentage 34,1. The measurements were performed on Obron scale BF511. Blood indicators remained within referential levels and the man had a medical diagnosis enabling him to perform physical activity within III intensity range. The man follows the rules of healthy life-style, especially with a view to physical activity [4].

2. Methodology and study subject

Studies have been performed in accordance with The Declaration of Helsinki and beforehand the following have been obtained: an agreement of bioethical commission for invasive and functional research and a positive opinion of a medical doctor allowing the said individual to take functional tests of circulatory-respiratory system under maximum effort. The measurements were conducted in Rehabilitation Department of PODIMED Hospital in Szczecinek and the following requirements have been met: the presence of defoliator and first aid kit in case of heart attack, the presence of a cardiologist, proper hygienic conditions for collecting research material. Due to blood characteristics, the sample was obtained in a nearby analytical laboratory of PODIMED Hospital so that, immediately after its drawing, it could be sent to analysis. Furthermore, before the study, initial analysis and assessment of analyzed features usability, tools calibration and applied research procedure have been performed. Biochemical analyses were conducted on Roche apparatus, model Modular P800, immunochemical analyses on Roche apparatus, model Cobas b 221, morphology on Abbot apparatus, model Cell-Dyn Ruby.

Determining time occurrence of spontaneous restitution is impossible without the analysis of exhaustion and rest periods. Their assessment is performed with the use of various indicators and their selection depends on load kind and load size as well as technical possibilities of the researcher. Thus, the selection of useful blood indicators was based on Łukaszewska et al. recommendations [5], hematocrit (HCT), mean corpuscular hemoglobin concentration (MCHC), mean corpuscular hemoglobin (MCH), blood platelet for mm3 (PLT), mean corpuscular volume (MCV), mean platelet volume (MPV), procalcitonin (PCT), red blood cell distribution width (RDW), platelet distribution width (PDW), pH indicator (pH).

Blood drawing and blood analysis were conducted in accordance with a previously drafted program, always at the same time of a day so as to avoid changes in physical ability resultant form one's daily biological rhythm. They encompassed the following: atmospheric pressure, pulse, systolic and diastolic blood pressure as well as body temperature. Blood was invariably drawn from ulnar artery or radial artery of upper left or right limb, while hand and forearm muscles were completely relaxed.

Standard physical effort is understood here as work of significant intensity. It is adopted by Ulatowski [6] that standard effort means systolic blood pressure within the range of 130-180 mm Hg and Brown indicator under 50. Applied physical effort lasted 66 minutes and comprised two subsequent cycles. First cycle consisted of the following loads: 2 minutes: 20 W, 4 minutes: 40 W, 2 minutes: 20 W, 4 minutes: 60 W, 2 minutes: 20 W, 5 minutes: 80 W, 2 minutes: 20 W, 4 minutes: 60 W, 2 minutes: 20 W, 4 minutes: 40 W and 2 minutes: 20

W. A number of cycles on cycle ergometer was measured with electronic meter and it ranged from 60 to 70 cycles per minute. During last 15 seconds of the second cycle, the studied individual remained on cycle meter and was advised to work freely without load, which was to prevent circulatory collapse. Cardiac monitor electrodes and blood pressure meter sleeve was put on in the last minute of standard work load.

Samples for analysis were collected for five consecutive days according to the following schema:

1. Before effort at 9.30, 10.30 am: blood, peripheral pulse, systolic and diastolic blood pressure, body mass and body weight

3. After endurance from 11.30 am

Early restitution period

a. blood features at 11.30 am, 12.30 pm, 13.30 pm, 15.30 pm.

b. SO2 from the end of physical effort to 11.51 am read every 15 seconds

c. peripheral pulse measured from the end of work to 11.51 am read every 15 seconds.

d. systolic and diastolic blood pressure from the end of physical effort to 12.50 pm read every 10 minutes

Late restitution period

a. blood features for 4 consecutive days at 8.00 am.

3. Statistical analysis

Because the study was conducted on a single individual the applied research methods embraced the following: calculating mean values of systolic and diastolic blood pressure and differences between obtained blood indicators. The results were calculated using the following computer program: Excel MS Office 2000. Selected features, in order to capture changes in their values, are presented on drafts.

4. Achieved results

Atmospheric pressure during the study ranged from 719, 8 to 732 Hg, body temperature from 36,6 to 37 C, systolic blood pressure from 120 to 121 mmHg before physical effort and it decreased from 145 to 110 mm Hg after its end. Diastolic blood pressure ranged from 78 to 81 mm Hg and from 88 to 87 mm Hg. Mean systolic and diastolic blood pressure values (M) ranged from 99 to 101 mmHg before the start of standard physical effort and from 116 to 98 mmHg after its end, draft 1. Blood oxygenation before physical effort was from 95 to 96 %, and after standard load from 92 to 94%. Pulse before physical effort was from 69 to 78 bpm and after standard load it gradually decreased from 111 to 77 bmp, draft 2. HCT percentage grew from the start of standard physical effort, then decreased until the end of the first hour after effort, and then increased again for the next 20 hours and decreased again for the next 36 hours, reaching numbers close to its initial values, draft 3. MCHC value decreased from the start of physical effort, and then increased during effort and decreased in the first hour after finished work. For another 30 hours, it grew up, and then for 24 hours went down, reaching the level close to the value after the end of standard physical effort, draft 4. MCH values significantly dropped from the first measurement until the end of first hour after finished physical effort. In the next hour, they significantly grew and then, in the following 36 hours, indicated insignificant changes and did not reach its initial values, draft 5. PLT value in blood for 56 hours after finished work displayed a declining tendency, while in the second hour it assumed the number almost identical to its initial value, and then it went down in the next 2 hours; in the following 15 hours it went up and in the next 36 hours significantly decreased in level as compared with its initial value, draft 6. MCV value decreased during standard load, then increased in the first hour after its end, and in the following 54 hours gradually dropped in value, reaching the level lower than its initial value, draft 7. MPV value, from the first initial measurement, dropped in value after physical effort and then for 2 hours grew, and then in the next 55 hours rapidly dropped again, not reaching its initial value, draft 8. PCT during physical effort gradually decreased as compared with its initial value, which lasted until the end of the first hour of early restitution phase. In the next hour, it went up and then gradually, for next 53 hours, went down, not reaching the initial level, draft 9. RDW percentage rapidly grew from the beginning of physical effort as compared with its initial value, and then, in the next 21 hours of restitution, it decreased only to increase again in the next 36 hours, reaching the level comparable with its initial value, draft 10. PDW percentage from the first measurement until the end of work increased, and then in the first hour after its end it decreased; in the next hour it rapidly went up and in the following 53 hours decreased again, not reaching its initial value, draft 11. Blood pH grew from the first measurement to the end of standard work, and then in the next hour rapidly dropped in value. From the 19th hour after physical effort, it gained in value only to decrease again; in the 56th hour it reached slightly bigger level than its initial value, but almost the same as after the end of work, draft 12.

5. Discussion

The significance of the indicated changes does not mainly depend on body stress reaction to the performer physical work. Also one's life-style, kind of physical exercise, time of day and method of collecting research material are important. As experiments have shown, also limb position, used tools and a person collecting research material are to be taken into account. Davis [7, 8], during experiments on dogs, pointed out that under effect of physical effort of similar load but different in kind (swimming and running) various values of the analyzed blood indicators may be observed. Swimming causes an increase in osmotic erythrocyte resistance and running causes its decrease.

Increased oxygen transportation from lungs to muscles and other active organs, as well as carbon dioxide from the same area to lungs and energy substances during maximum physical effort, are conditioned not only by increased heart muscle work but also by adjusting total peripheral vascular resistance to the enhanced blood flow. Adaptation changes are connected to proper active and passive blood and vessels distribution. Skeletal muscles receive around 90% of blood from cardiac output. Total vascular resistance drops. Systolic pressure rises on average to 200 mm Hg, diastolic to 90 mm Hg [9]. The effect of blood pressure on burdening the body with work of the same intensity indicates variations dependent on age, sex and physical abilities as well as other external factors [10]. Among the people of exceptional physical fitness, the changes in blood pressure under the effect of maximum physical effort are relatively stable: in 96% systolic blood pressure rises to 180 mm Hg and diastolic pressure slightly drops [11]. The effect of blood pressure among people of average physical fitness on being burdened with maximum physical effort varies considerably. Normotonic reaction appears only among 23% of the studied group. In majority of the individuals, 64%, the tendency for hypertension (big increase in systolic pressure) was observed, which manifested itself in hypertension reaction in 37% of the studied individuals. Dystonic reactions (with big drop in diastolic blood pressure below 40 mm Hg) were observed in 20% of the individuals and hypertonic (with increase of systolic blood pressure above 95 mm Hg), in contrast to its former occurrence, among 7 %. Furthermore, 13% of individuals of average physical fitness showed a tendency to hypotonic reaction to maximum physical effort (hypotonic reactions and late blood pressure increase) [11, 12, 14, 14]. Górski [15] claims that systolic blood pressure increases simultaneously to exercise load and may reach even 250 mm Hg. Diastolic pressure does not change significantly. While performing physical effort with upper limbs, with the same load as with lower limbs, increase of systolic pressure is bigger. Also a small increase in diastolic pressure is noted. According to Nazar et al. [16] systolic blood pressure rises during physical effort, reaching stable state after 3-4 minutes and, during long-lasting physical effort, it slightly decreases. At the same time, progression of tiredness is accompanied by slight increase in systolic pressure and this increase is proportional to work load as it depends on cardiac output, which, in turn, grows together with intensity of physical effort. Diastolic blood pressure, measured during effort with Korotkow's method, stays the same, decreases or indicates a slight increase. Mean blood pressure during physical effort significantly changes, due to increase in systolic pressure. Artur Jaskólski and Anna Jaskólska [1] claim that, as a result of aging, left heart chamber walls thicken which, in turn, causes their mass growth and is partially connected to an increase in systolic pressure caused mainly by growing walls' inflexibility of arterial vessels. This blood pressure in elderly people is of around 35 mm Hg higher than in the young people. Furthermore, during physical effort, blood pressure reaches higher values in people who have it higher also during rest period. Hence, though elderly people have lower stroke volume and cardiac output, their systolic blood pressure is nevertheless higher during maximum physical effort than in younger people, which may be a result of arterial vessels condition. At the same time, maximum systole frequency reaches its highest value (around 195/200 bpm) at the age of 20-30, and then it gradually decreases. One may assume, then, that applying a rule determining maximum systole frequency as 220 – age (years) to a 65 year-old man one would expect 115 bpm, but the measurements performed on the studied individual showed a significantly higher value. Therefore, one must assume that older people may have a higher systole frequency than it would be expected using the above mentioned formula, though these figures decrease with age.

Burdening one's body with maximum physical effort that requires energy consumption (to 10-12 calories per minute) and heat production, especially in skeletal muscles and liver, causes a rise in body temperature to 37,5 – 38,5 C, or even to 39 C, while one simultaneously gives up heat through the skin. Internal body temperature, measured within natural body cavities, goes up gradually in the initial period of effort and then stabilizes itself on a set level that is higher than during rest period [17]. Other authors suggest that elderly people have worse thermoregulation, which results in difficulties to maintain body temperature. The elderly have higher body temperature and increased systolic frequency during physical effort performed in hot environment. These changes are caused by the said lower effectiveness of steaming mechanism [1]. Plowaman and Smith [18] also claim that endurance physical effort leads to significant lowering of rest pulse frequency, systolic and diastolic blood pressure.

Under the effect of one-time physical effort, part of blood plasma water is moved to space outside vessels, which leads to decrease in circulatory blood volume. A reflection of these changes is post-effort increase in hematocrit [19]. Hoenak at al. [10] indicated that in rowers intensive physical effort decreases the number of erythrocytes and hemoglobin as well as lowers hematocrit level. The measurements were performed during intense physical training. Patriarca and Topi [21] determined that, after finished work on cycle ergometer that lasted until exhaustion (load 1250 kgm/min and average time 14-45 minutes), hematocrit increased during the effort but after its end it came back to the initial value. Erythrocytes level decreased of statistically insignificant number and hemoglobin lowered after effort and increased during rest period; reticulocytes, however, increased after effort and then decreased to the initial level. De Lanne et al. [22] showed post-effort increase in hemoglobin and hematocrit. They also noted that severe and long-lasting physical effort lowers erythrocyte number and hemoglobin levels.

Hemoglobin, whose main role is oxygen transportation, show also some features of being a buffer. In lungs, where it undergoes oxygenation, hydrons are released and they partially balance pH increase in result of breathing out carbon. In tissues, however, hemoglobin, giving up oxygen, creates conditions for attaching hydrons and in this way it raises pH. Hemoglobin buffer comprises around 35% of all buffers [1]. From Jager at al [16] one may learn that hemoglobin concentration in blood increases under the effect of physical training. The authors underline, however, that this effect often does not occur and then Hb concentration lowers. Under the effect of physical effort in humans, the number of red blood cells in circulatory blood changes. The character of these changes depends on many factory and results achieved by various authors are contradictory. Discussing shifts in erythrocytes, one must remember that these changes directly depend on erythropoiesis and platelets disintegration intensity [19]. Holmgren et al. [23] indicated that after finished physical effort hemoglobin rises. Similar conclusions were drawn by Morehouse and Miller [24]. Other researchers indicate that similar physical training results in lowering erythocytes number [25, 26, 27] or their decrease after finished work [28]. Halicka et al. [29] marked erythrocytes' osmotic resistance in sportsmen and compared achieved results with generally accepted norms. Research were conducted on a group of professional sportsmen comprising 20 women and 20 men. A decrease in erythrocytes' osmotic resistance was noted both in females and in males. Authors highlight also their low reticulocyte level, which remained within the low norm range, as well as statistically unchanged increase in mean red blood cells volume and higher hemoglobin concentration in a single erythoryte both in men and in women. Analogous changes were described by Goldwich et al [30] who determined a decrease in erythrocytes osmotic resistance in training rats, with no changes in hemoglobin concentration and hematocrit levels. Some other studies suggest that observed shifts in erythrocytes depend mostly on changes in circulatory blood volume taking place during physical effort [31]. This view is not in reflected in studies which show no simultaneous increase in erythrocytes and hematocrit [21].

Lubańska-Tomaszewska [27] marked hematological changes in rats under effect of long-term physical training and one-time physical training. The animals were divided into two groups. In the first group, rats run on electronic treadmill until exhaustion. In the second group, they were trained for 33 days and running time was gradually prolonged so that on the last day it lasted 69 minutes. The author received the following results: one-time physical effort caused increase in erythrocytes and hemoglobin concentration. One-time physical effort, as well as physical training, caused a decrease in reticulocytes in circulatory blood as a result of blocking erythroblasts proliferation in bone marrow. Physical training led to a decrease of erythroblast level in circulatory blood. The author believes that observed changes in red blood cells system are a consequence of triggering erythrocytes from blood "reservoir" and that they are caused by post-effort blood congestion. Post-training changes, leading to a drop in erythrocytes, may be caused by enhancing destructive processes of red blood cells, storing erythrocytes in a spleen and muscles as well as post-training increase in circulating blood. The conception that under effect of physical training there occurs a release of erythrocytes from blood "reservoirs" is nevertheless questioned in light of research that have not determined the existence of blood "reservoirs" in humans [32]. Other studies, however, prove that some organs are flexible and therefore they may store some amounts of blood, which are released in the moment of increased oxygen demand (i.e. during physical effort). Into this group one may include liver, capable of releasing several hundred milliliters of blood, spleen – 100 ml, big veins in visceral area – 300 ml, lungs – 100- 200 ml. One may assume that many observed shifts in erythrocytes, reticulocytes and hemoglobin levels depend on physic-chemical changes in blood plasma and red blood cells, being a result of physical efforts. And thus an increase of CO2 in blood, determined during physical work, and the shift of pH towards acid area may lead to a decrease in red blood resistance and thus contribute to the intensification of hemolytic processes, leading to a drop of erythrocytes in circulatory blood. Repetitive physical effort probably affects also red blood cells metabolism [1]. Swallen [33] noticed that when a red blood cell remains in the reduced glucoses environment, it may disturb erythrocyte energetic balance and decrease its osmotic resistance. Thus, one may assume that hypoglycemic states, which occur in sportsmen's bodies during long-term physical efforts, are not without effect on lowering erythrocytes osmotic resistance.

Along with the increase of physical effort above 50% of maximum oxygen absorption, pH decreases due to absorbing energy from anaerobic processes, the result of which is lactic acid

[1]. Physical effort, as a consequence of metabolic products from working muscles concentration, and especially that of pyruvic and lacid acids, leads to metabolic acidiosis, which is corrected inter alia by calcium ions in blood. In case of metabolic acidiosis lasting a few hours or days the said process results in releasing Ca from bones [34]. The increase in H+ is also not without significance for pH levels. During intensive work, as a result of glycolysis activation and H+ accumulation, pH decreases. In extremely exhausted glycolytic muscles their internal pH drops from 7,0 during rest period to 6,2 after effort [35]. As work load increases, but for the drop in Ph, the growth in pyruvic acid and lacid acid, CO2 pressure decreases. A degree of said substances accumulation may be considered the measure of “oxygen debt” [19, 36]. A relation of hemoglobin to oxygen depends inter alia on acidity of the environment (pH), 1,3-DPG concentration and temperature. During long-term work, amino acids decrease, urea increases – to 48mg% during rest period; and 55% is a sign of not fully realized restitution, which indicates the need to prolong rest period (40mg% is considered a norm). The level of lactate and pH, surplus of alkali and other indicators of acid-alkali balance, also have some value in the assessment of restitution effectiveness [2].

Based on presented review of literature, one may determine that various authors' results were obtained on varied human material, with varied physical efforts as well as with the tools of varied sensitivity. The above quoted specification of spontaneous restitution is corroborated by the configuration of indicators accepted for the described analysis, namely pulse frequency, blood oxygenation, blood pressure features and selected blood indicators. Unevenness of restitution and its phase character manifested itself in all analyzed indicators. The period of early spontaneous restitution in the studied 61 year-old man takes place between the 3rd and 4th hour of rest period, which confirms the results of other authors [2, 3, 5]. As such, one may assume that the period of late spontaneous restitution begins in at least the 5th hour of rest period. Its length is probably dependent on intensity, volume, work load kind, morphological and somatic features, as well as sex and age. In case of the studied individual, one may assume that it takes place in the 45th hour of rest period. Based on presented discussion, if hour “0” is the end of work, the period of early restitution lasts 3-4 hours and late restitution the following 41 hours. Hence, there remains the question of determining supercompensation phase. From blood indicators analysis, one may, though with great caution, assume that it takes place around the 33rd hour of rest. These claims, however, are true only of this particular individual. The presented modulation image of blood indicators is after all affected by his life-style, starting involution changes within the muscle system, circulatory system and respiratory system. After some time, during submaximal work, one achieves activity balance. In the people in their sixties (especially among people living sedentary life-style) the stabilization of cardiac output, blood pressure and lung ventilation takes more time. It is partially caused by unfavorable changes in control mechanisms. Also due to lower physical fitness, particular to the studied individual, restitution of rest values is prolonged. There increase also a part played by anaerobic processes and the heat produced during work is disposed of more slowly [1]. The measurements performed on bigger population, with rigorous use of described procedure, may indicate different, but approximate results.

8. Conclusions

Based on analysis of literature and changes in selected blood features one may formulate the following conclusions:

1. Process of early and late restitution after endurance effort in 61 year-old man runs according to assumed time intervals. The period of early restitution lasts 3-4 hours, and late restitution for the next 41 hours.
2. In order to determine more accurate time intervals of early and late restitution as well as supercompensation phase a research on bigger population of varied age and sex, and conducted after physical effort engaging various motoric function and various parameters, is required.

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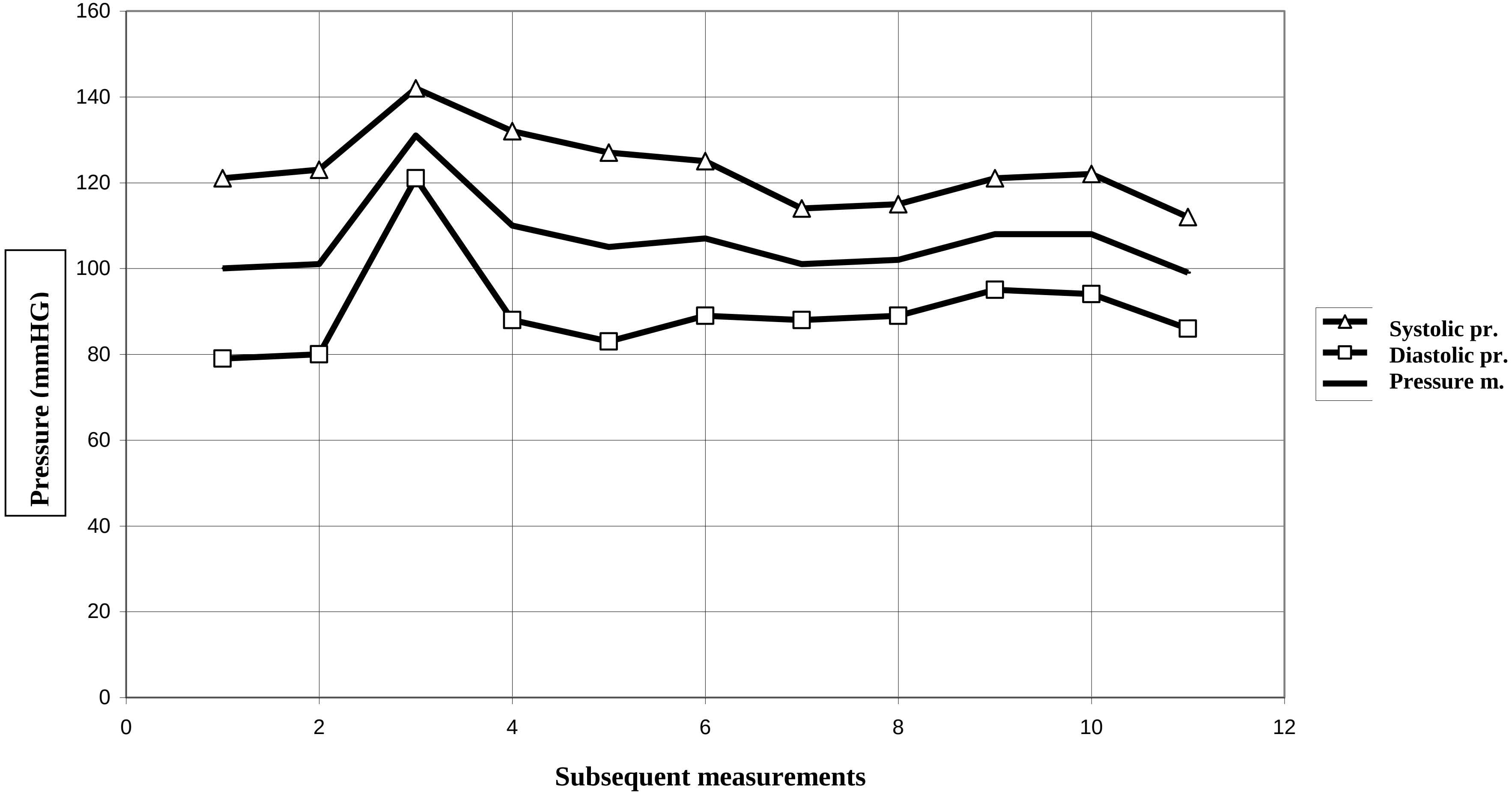
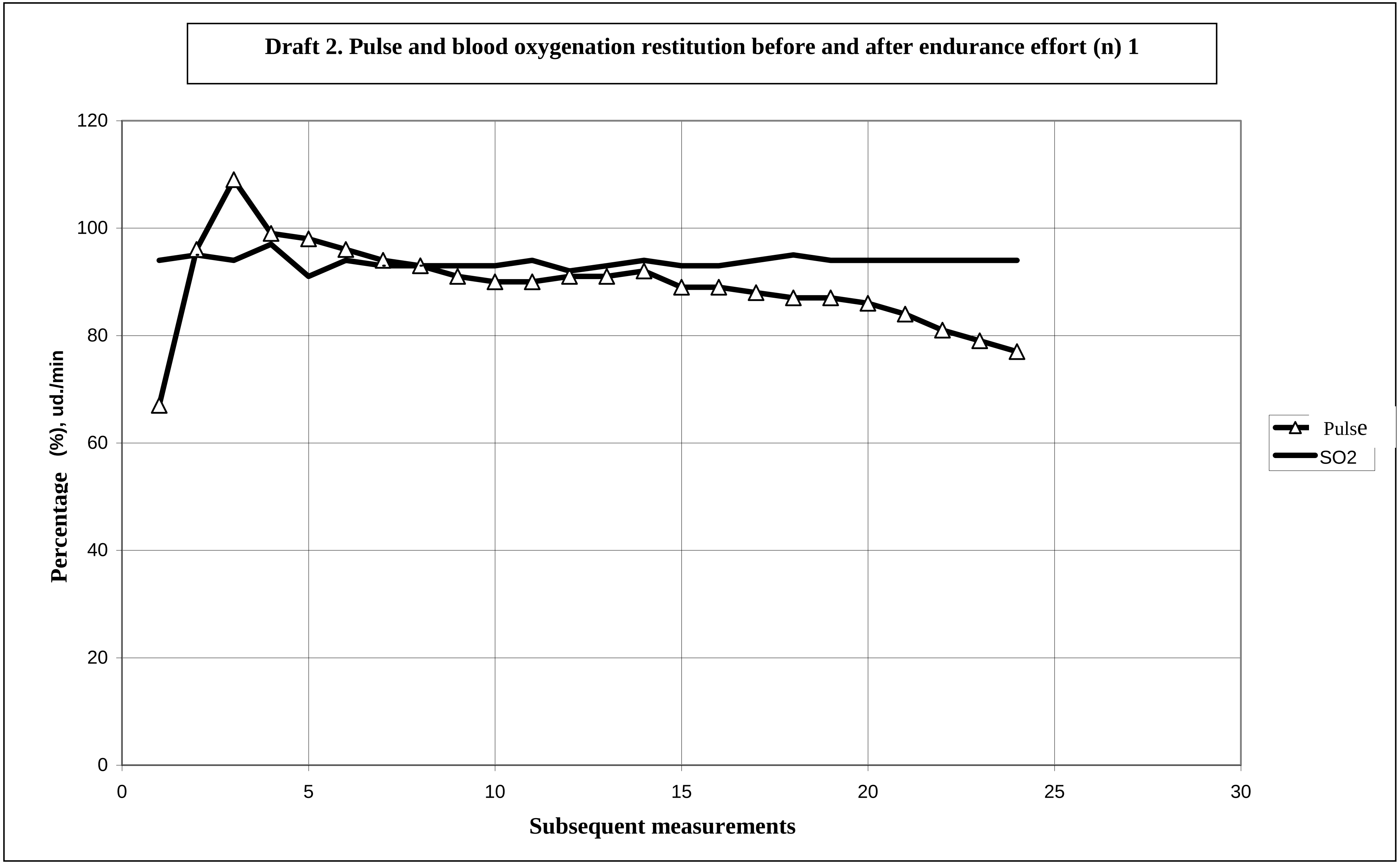
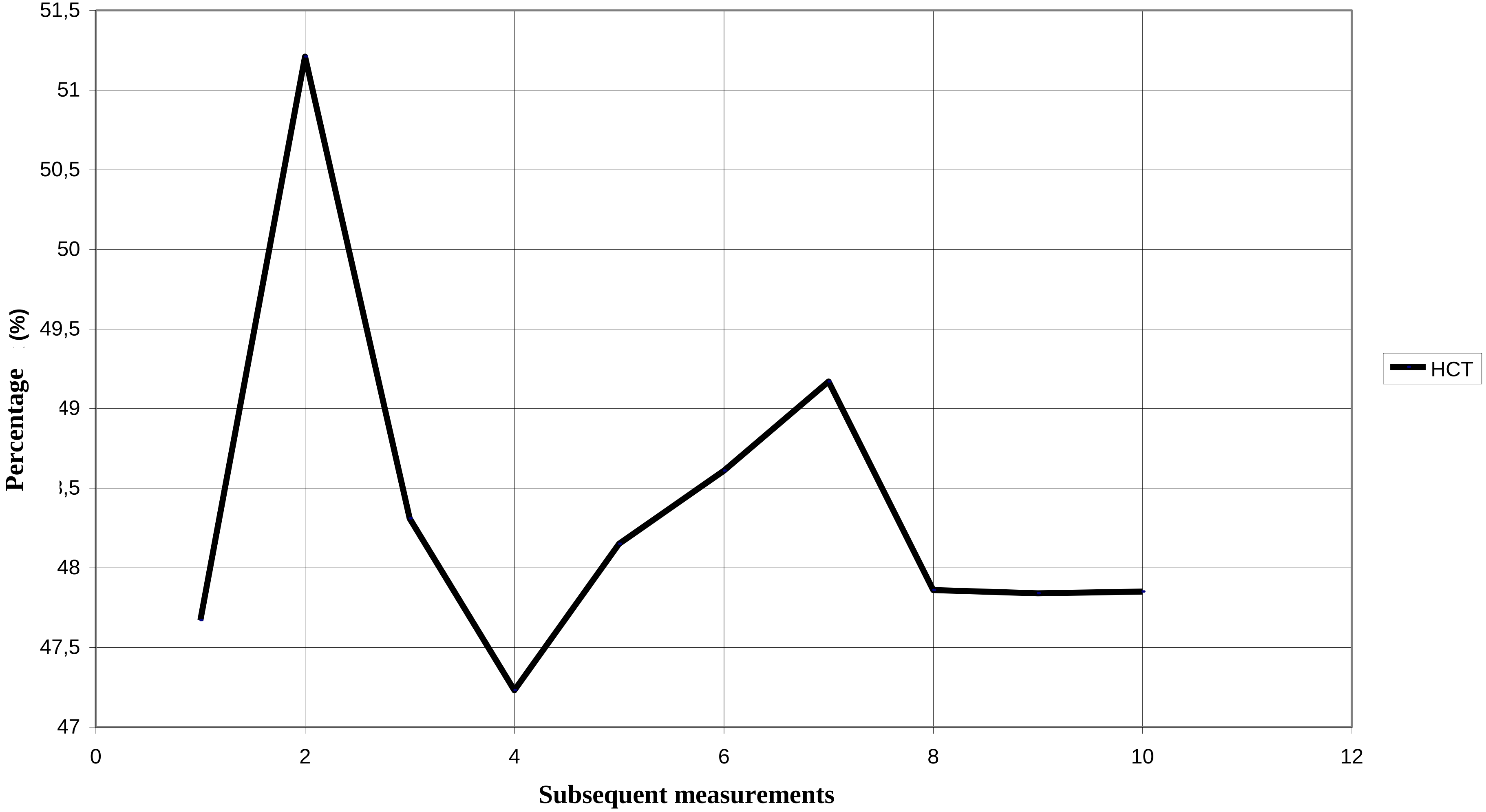
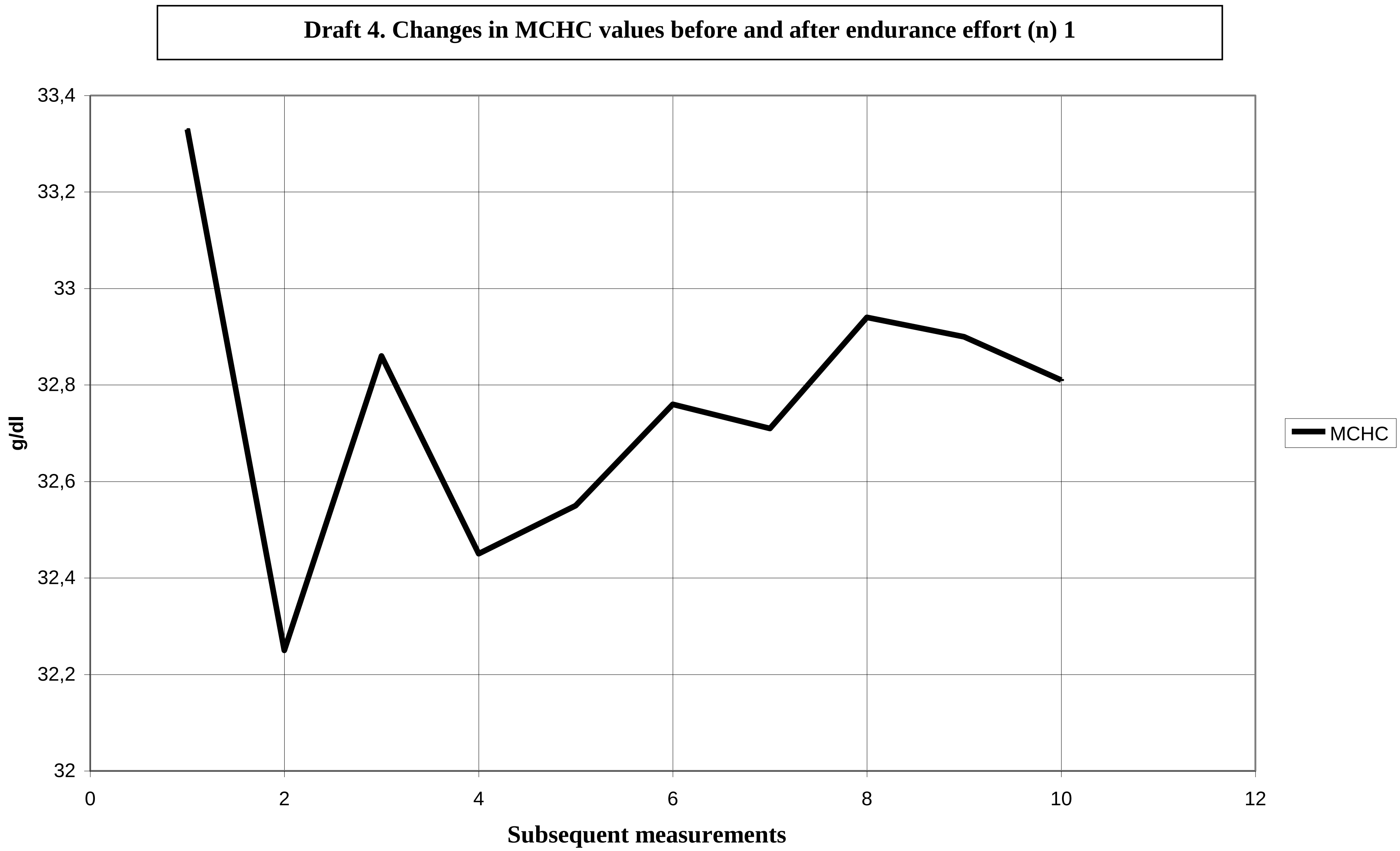
Draft 1. Restitution of systolic and diastolic blood pressure and their mean values before and after endurance effort (n) 1.



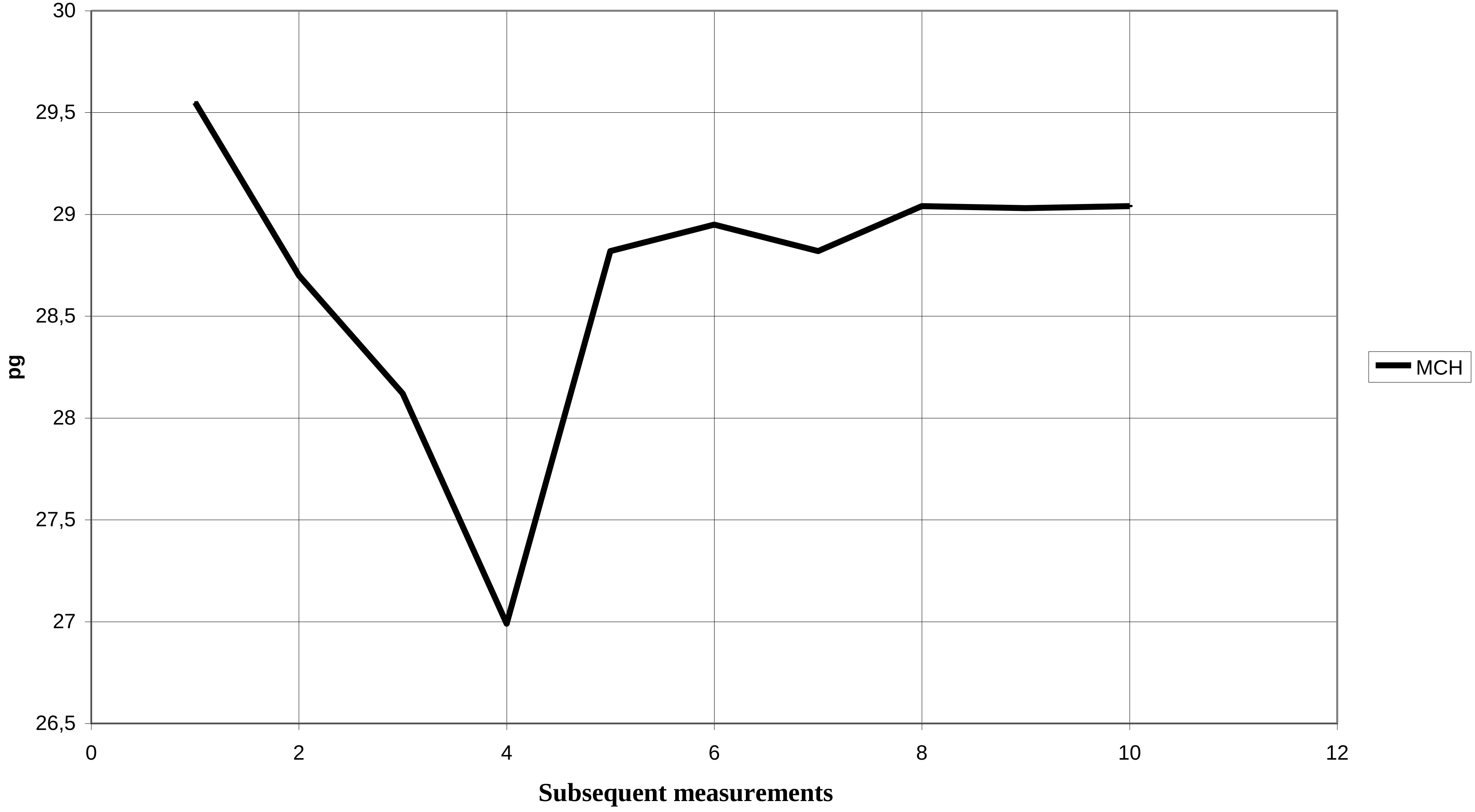

Draft 2. Pulse and blood oxygenation restitution before and after endurance effort (n) 1
Percentage (%), ud./min
120
100
80
60
40
20
0
0
5
10
15
20
25
30
Subsequent measurements
Pulse
SO2

Draft 3. HCT percentage changes in blood before and after endurance effort (n) 1

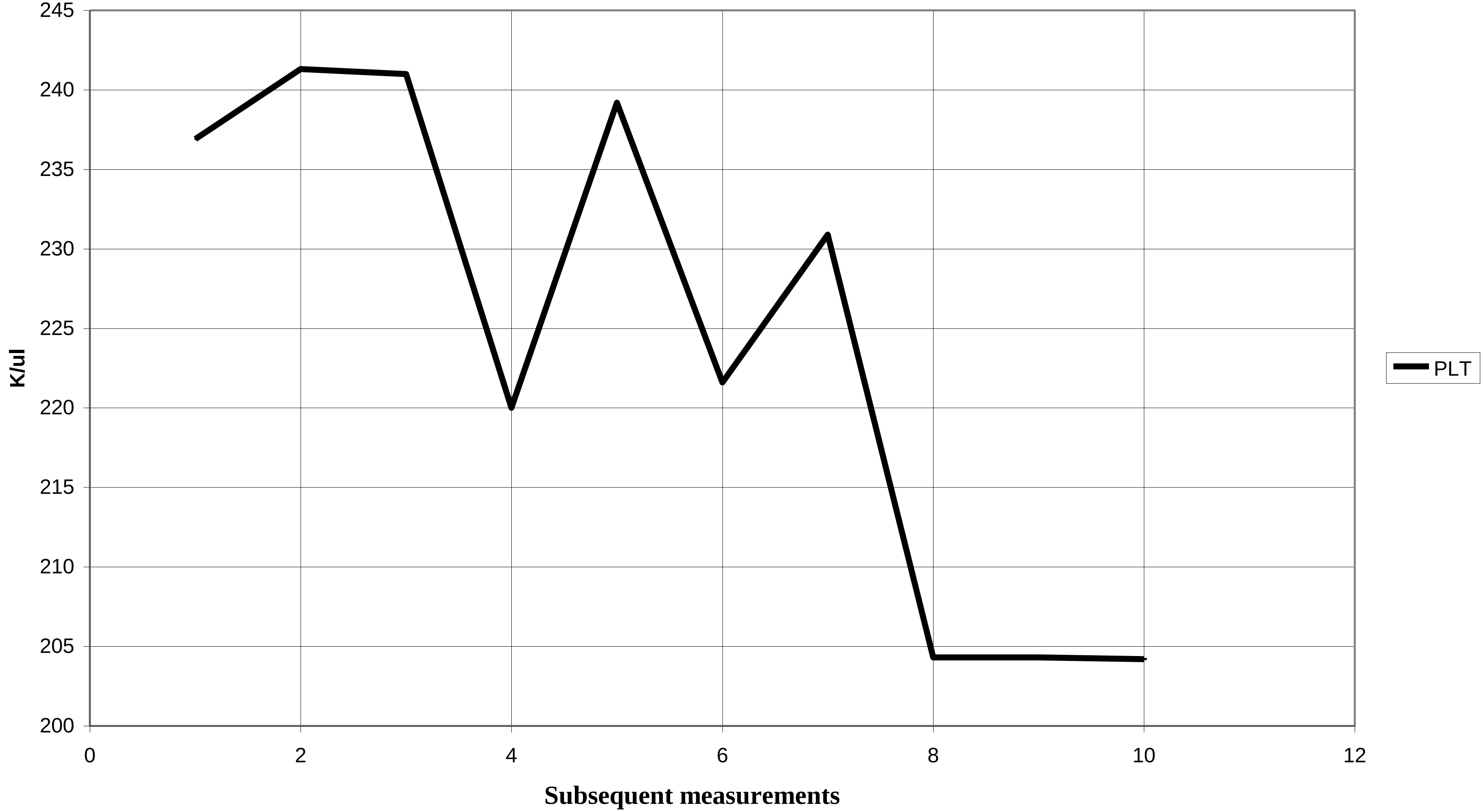



Draft 4. Changes in MCHC values before and after endurance effort (n) 1
33,4
33,2
33
32,8
32,6
32,4
32,2
32
g/dl
0
2
4
6
8
10
12
Subsequent measurements
MCHC

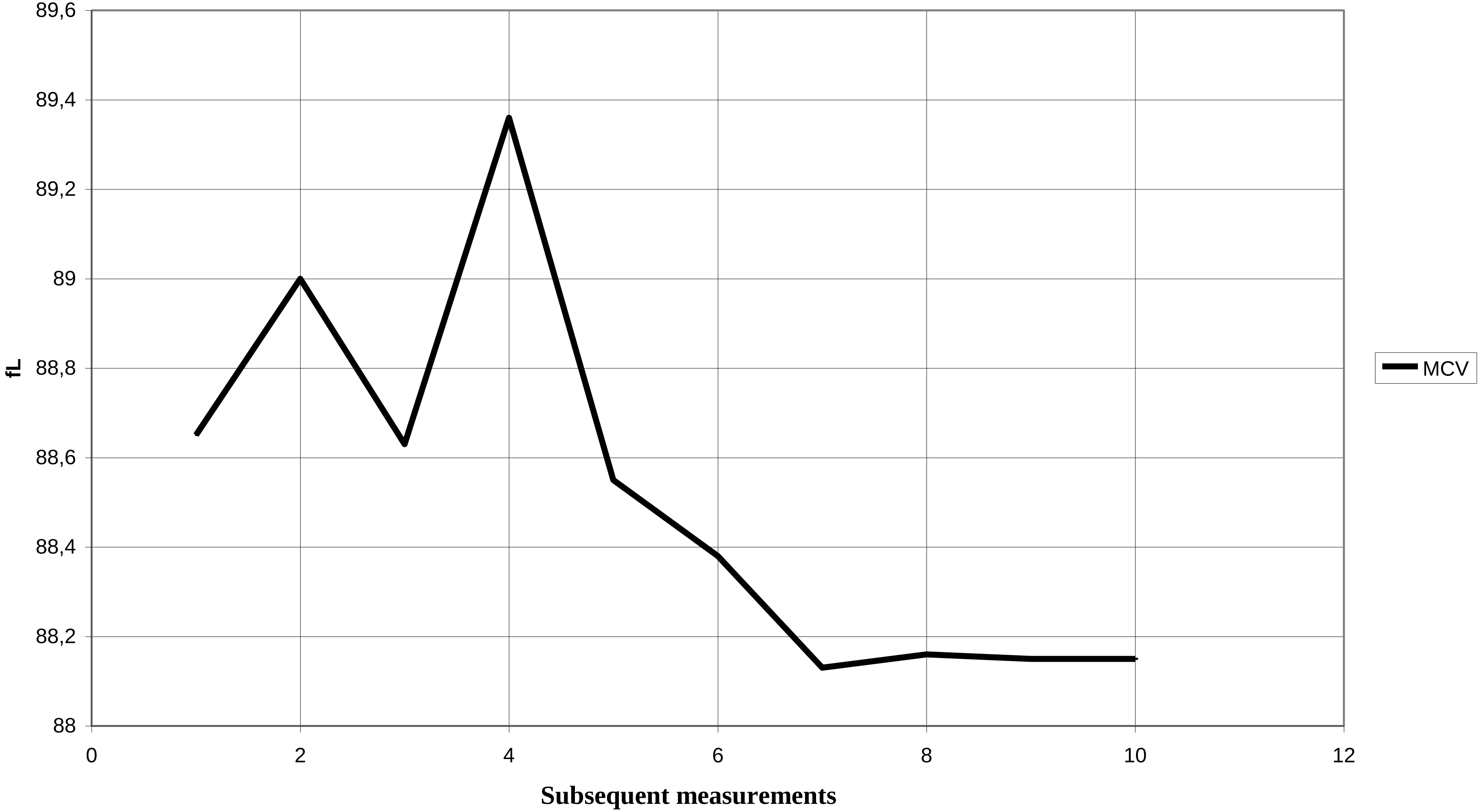
Draft 5. Changes in MCH values before and after endurance effort (n) 1

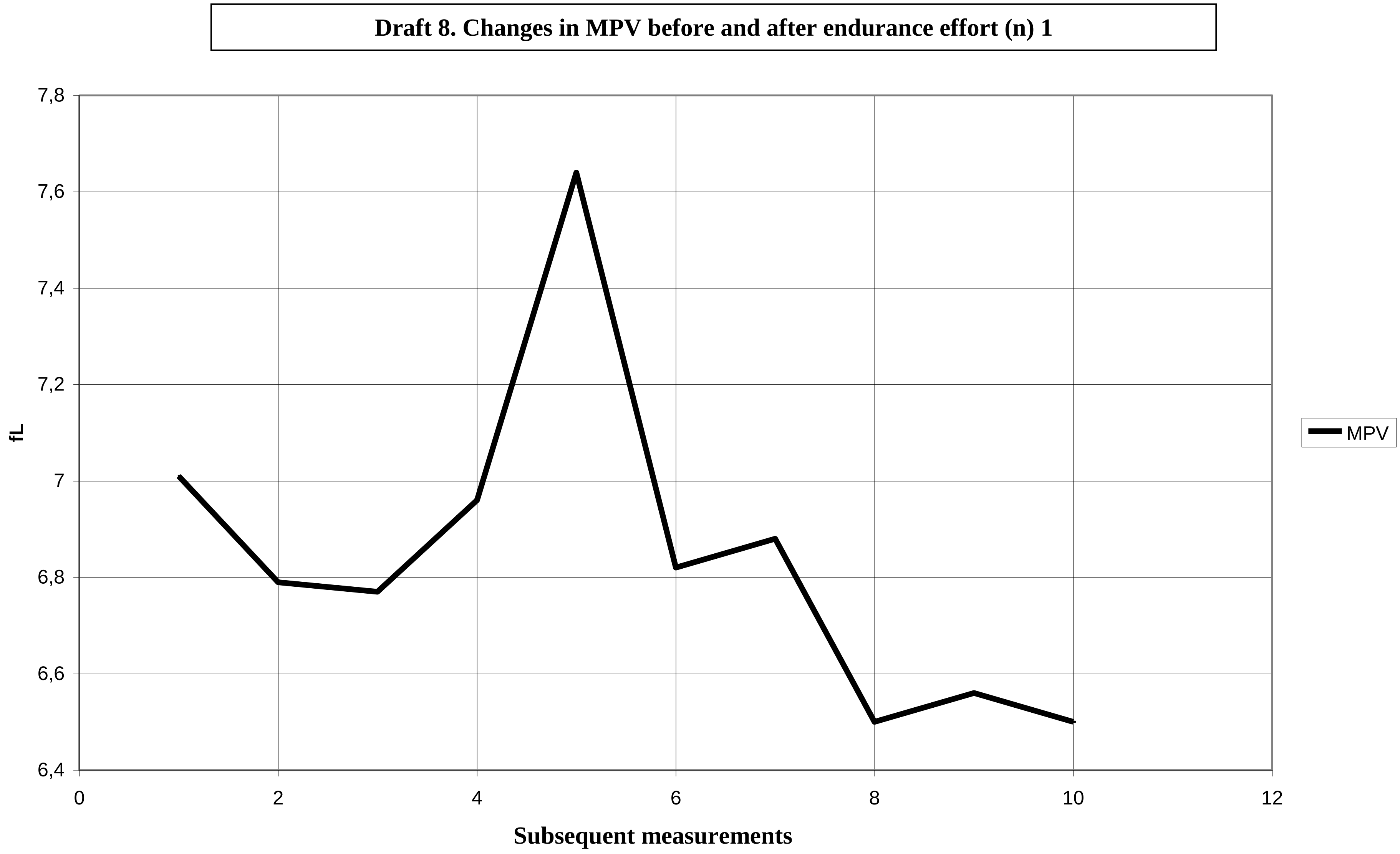


Draft 6. Changes in PLT before and after endurance effort (n) 1

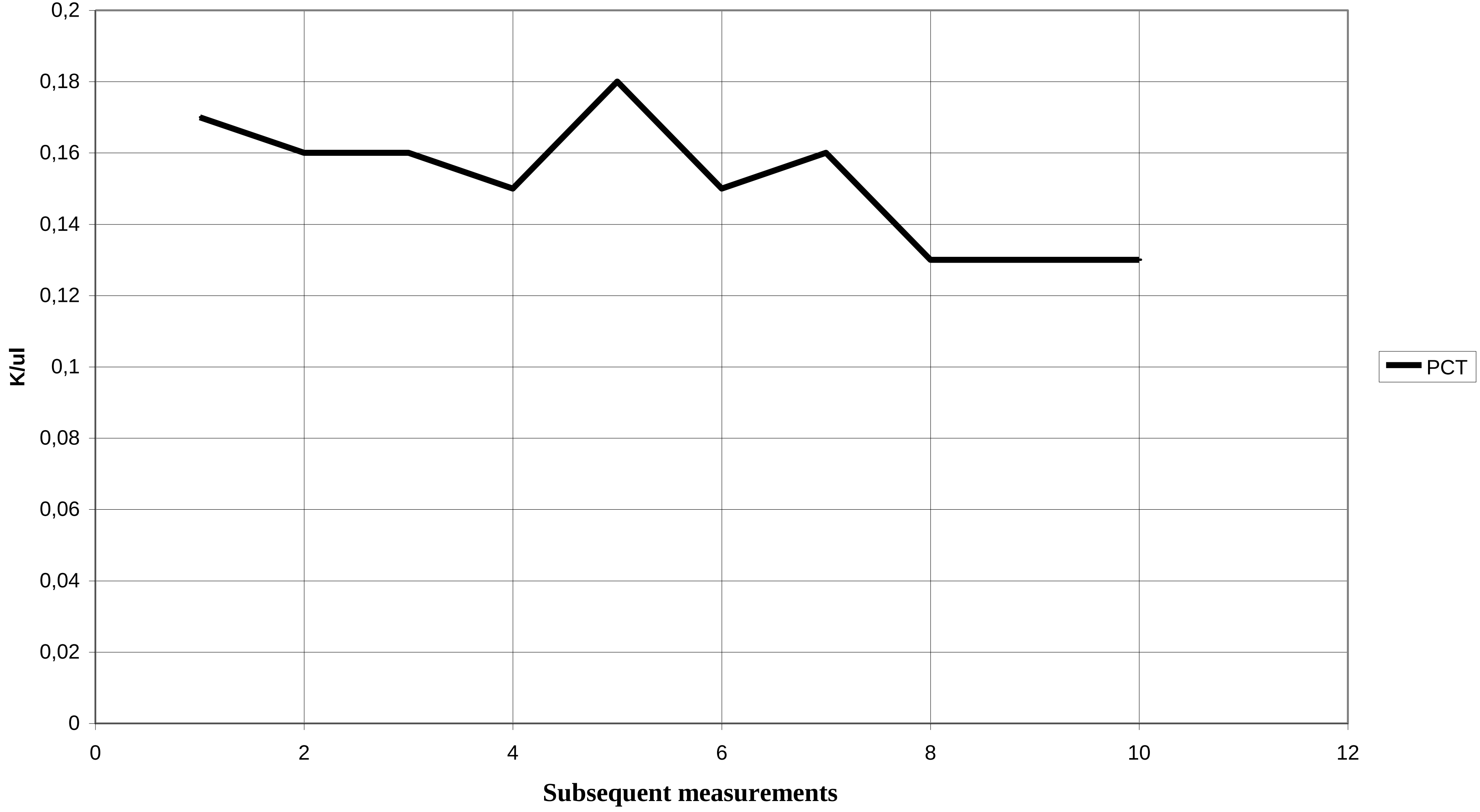


Draft 7. Changes in MCV before and after endurance effort (n) 1

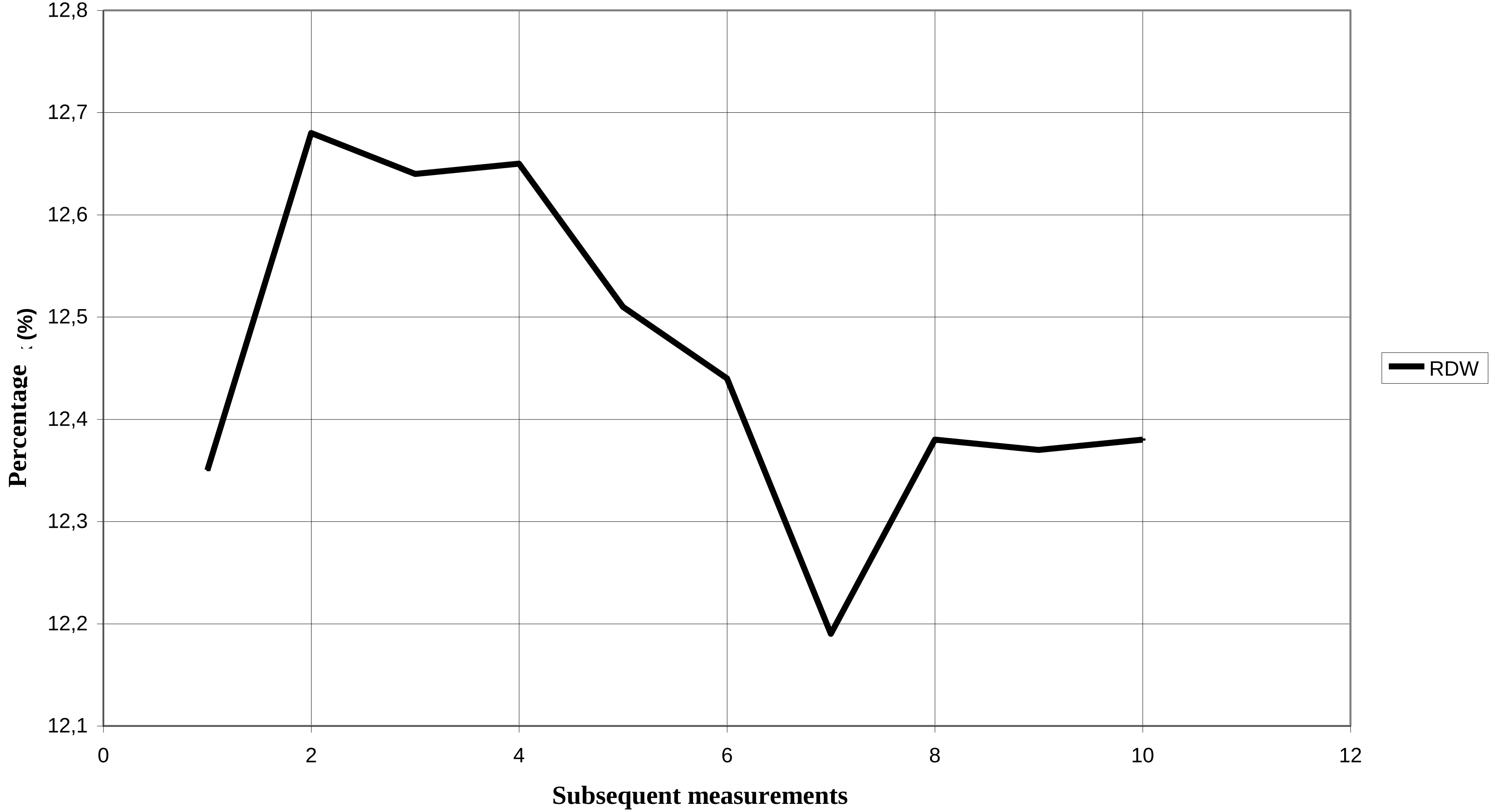


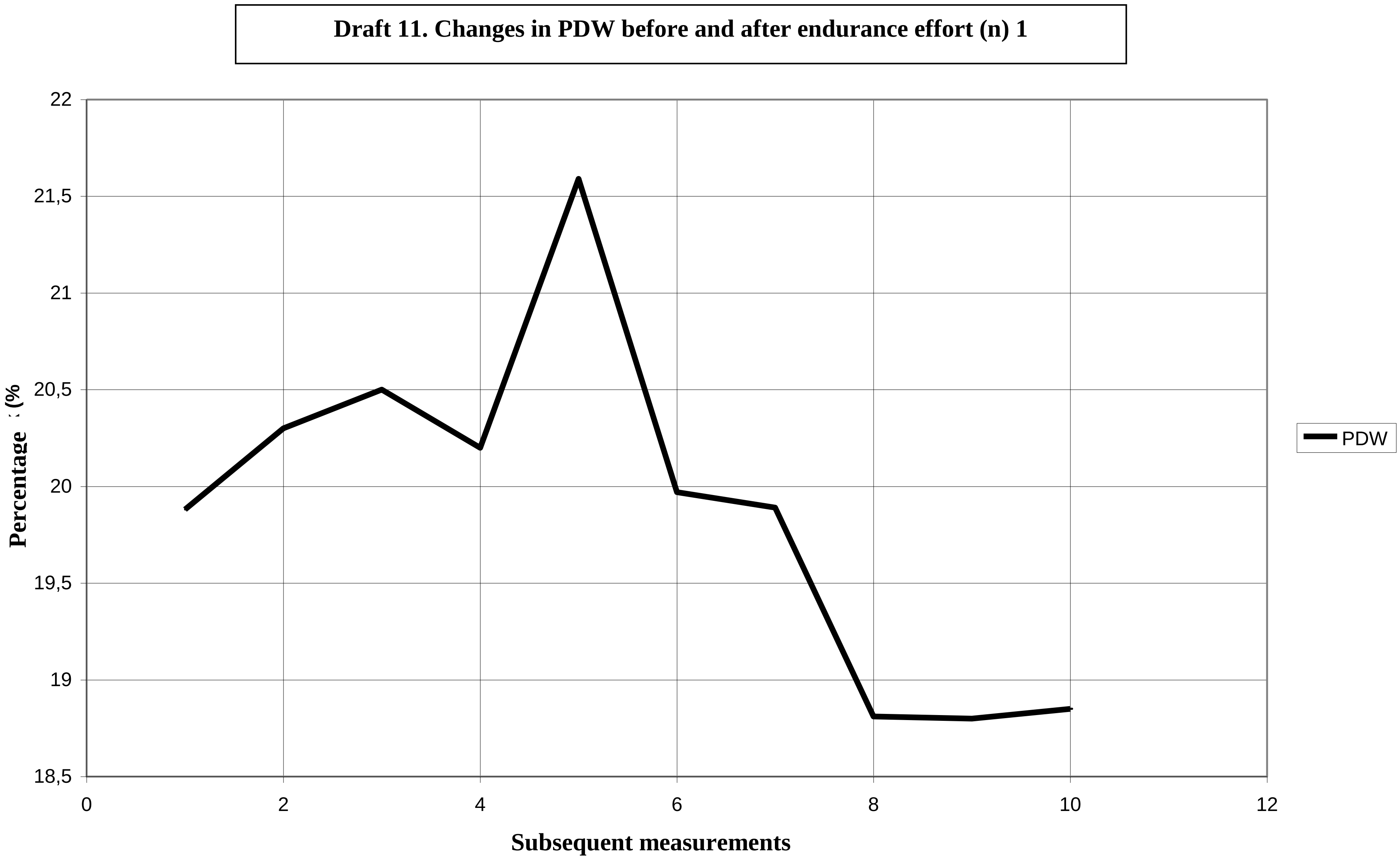

Draft 8. Changes in MPV before and after endurance effort (n) 1
7,8
7,6
7,4
7,2
7
6,8
6,6
6,4
fL
0
2
4
6
8
10
12
Subsequent measurements
MPV

Draft 9. Changes in PCT before and after endurance effort (n) 1



Draft 10. Changes in RDW percentage before and after endurance effort (n) 1




Draft 11. Changes in PDW before and after endurance effort (n) 1
22
21,5
21
20,5
20
19,5
19
18,5
Percentage (%
0
2
4
6
8
10
12
Subsequent measurements
PDW

Draft 12. Changes of pH in blood before and after endurance effort (n) 1