Part A

1. State a hypothesis predicting the relative order of total diuresis under each experimental condition.

If the blood pressure decrease, the baroreceptors send a signal to the brain as a response, and the sympathetic nervous system cause vasoconstriction activating the afferent arterioles of the nephron. Because of this, the glomerular filtration rate decreases its pace, and the sodium absorption in the distal tubule of the nephron increase to normalize the blood pressure. In conclusion, a decrease in blood pressure causes a decrease in GFR.

When doing exercise, blood pressure will increase the most out of all conditions, therefore the GFR will have the biggest increase. When sitting, blood pressure will remain slow but not as slow as lying down. This is because the heart is at the same level as most parts of the body when lying down. Consequently, the heart won't have to waste a lot of energy to circulate blood in the body and the blood pressure will be lower. Sitting passively and consume only water as normal won't show any radical changes in the diuresis rate and it should be low due to the amount of water drank compared to the other conditions.

2. Plot a line graph of mean diuresis rate Vs time for each experimental condition

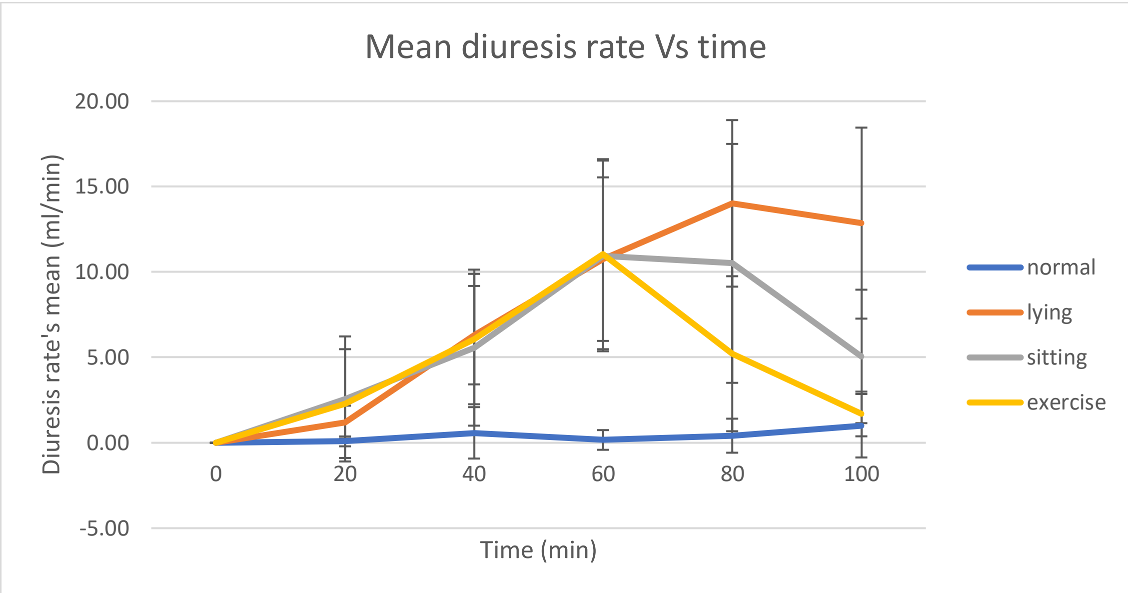

Figure 1. A graph showing the mean diuresis rate Vs the time for each experimental condition.

3. Briefly describe the experimental data for each experimental outcome (each condition).

Sitting, exercise and lying values grew considerably until a peak at 60 min was reached. After this period, the conditions of exercise and sitting started to decrease: the mean diuresis rate fell dramatically in exercise and gradually when sitting down. Drinking water as normal remained steady with very low values with a slight growth at 80 minutes.

4. Discuss the appropriate homeostatic response under each condition

In this experiment, the highest urine output was lying down, followed by sitting, exercise, and normal with the lowest value. The only condition that fits with the theory is drinking water as normal. This value shouldn't fluctuate, the urine output should be low because not a lot of water was drunk before the data was measured.

When the urine output under exercise exposure should be one of the highest values out of the four conditions, as it was mentioned on the hypothesis, it was one of the lowest ones. When exercising, the heart focus on circulating blood to the most important places in the body to cope with the changes that occur when doing exercise. Because of this, the renal blood flow is reduced and the GFR decreases.

When sitting and lying down, the diuresis rate should be low since the blood pressure is not higher than doing exercise. This could be because the water loading could affect the blood pressure. Water drinking raises sympathetic activity, and it increases blood pressure. As a consequence, GFR will increase.

Part B

1. Calculate the control and investigative rates of diuresis and glomerular filtration rate (GFR).

Table 1: Control group data.

Volume of urine	Sample time	time (min)	Diuresis rate (ml/min)	plasma inulin conc (mg/ml)	Urine inulin concentration (mg/ml)	GFR(ml/min)
250	09:00	20	12.5	1	30	375
330	09:20	20	16.5	1	31	511.5
350	09:40	20	17.5	1	32	560
200	10:00	20	10	1	31	310
189	10:20	20	9.45	1	25	236.25
150	10:40	20	7.5	1	32	240
100	11:00	20	5	1	35	175
80	11:20	20	4	1	28	112
20	11:40	20	1	1	44	44
10	12:00	20	0.5	1	88	44

Table 2: Investigative group data.

Volume of urine	Sample time	time (min)	Diuresis rate (ml/min)	plasma inulin conc (mg/ml)	Urine inulin concentration (mg/ml)	GFR(ml/min)
180	09:00	20	9	1	27	243
190	09:20	20	9.5	1	28	266
160	09:40	20	8	1	24	192
140	10:00	20	7	1	20	140
100	10:20	20	5	1	18	90
70	10:40	20	3.5	1	6	21
62	11:00	20	3.1	1	7	21.7
43	11:20	20	2.15	1	6	12.9
12	11:40	20	0.6	1	1	0.6
2	12:00	20	0.1	1	0	0

2. Plot two graphs using the data calculated in B1, one that compares the diuresis rates and one that compares the GFR.

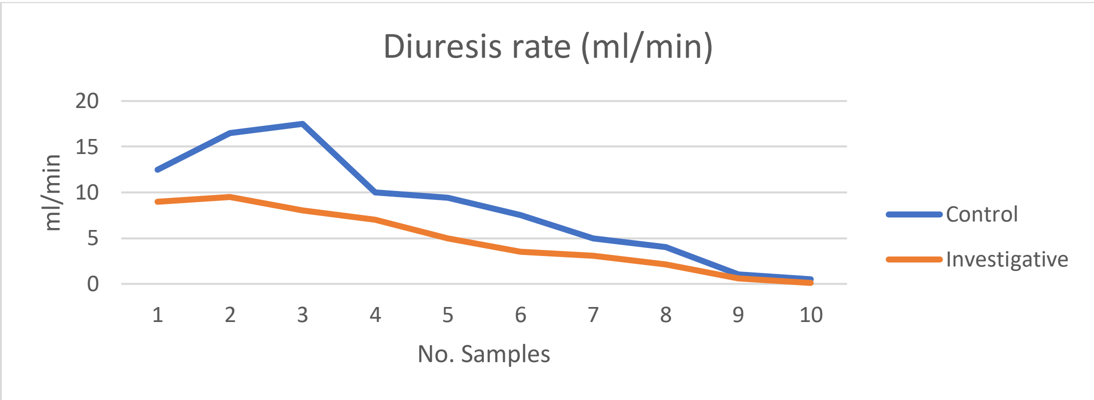

Figure 2. A graph showing the diuresis rates comparison of both control and investigative groups.

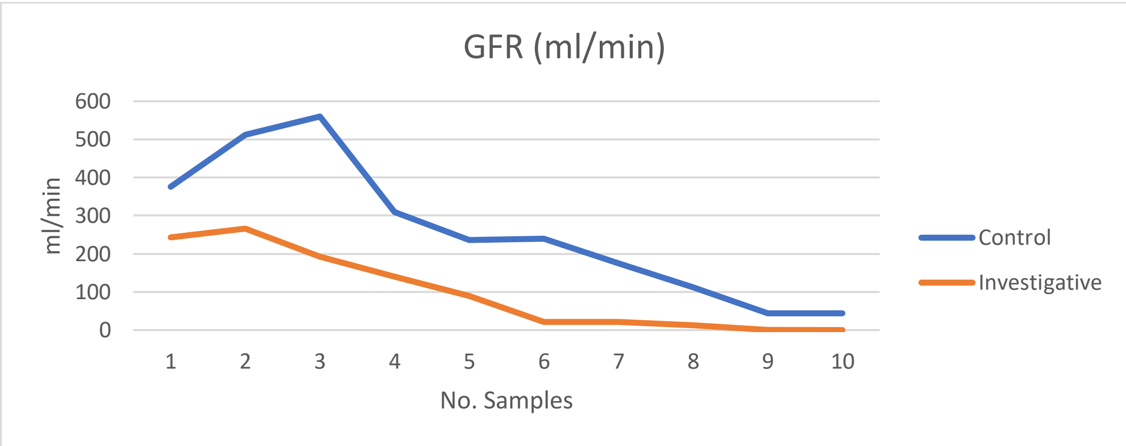

Figure 3. A graph showing the GFR comparison of both control and investigative groups.

Comparing both conditions (control and investigative) in figures 2 and 3, both rates were significantly lower in the investigative test than in the control. It remained steadier and it fluctuated less. The range for GFR is very large, it can go from 90 to 120 ml per minute in an adult male. However, the diuresis rate and the glomerular filtration rate are considerably low in this case. This fact may lead to the conclusion that something is not working as it should in the kidneys.

3. Give a brief discussion (approximately 10 lines) of the cellular mechanism of one cause of renal failure.

Acute kidney failure happens when the kidneys stop working and are not able to filter waste products from the blood. This condition could occur when the patient has an illness that slows the renal blood flow such as heart disease, liver failure, blood loss, or the use of drugs among others. Most of the issues that cause renal injury are located in the nephron segments: the proximal tubules and thick ascending limb; and the renal outer medulla. The tubular epithelial are more commonly affected and these cells are detached from the membrane causing damage in the formation of tubular casts. The regulation of fluid balance is complicated and implicates the cardiovascular system, the urinary system, the endocrine system, the respiratory system, and the skin.

Part C

1. State hypotheses predicting what the effect of facial immersion on heart rate will be in each test relative to control (breathing in air) and the other conditions

The initial stimuli come from receptors on the upper part of the face due to cold water. The central nervous system processes it by sending neural signals produced by the medulla oblongata to the respiratory and cardiovascular centres.

On the one hand, the neural signals heading towards the respiratory muscles produce apnea as a response, this means that the lungs prevent aspiration of water by holding the breath.

On the other hand, the ones going to the cardiovascular system can take two different directions in the autonomic nervous system. The first one is the parasympathetic division, the neural signals are received by the heart, which initiates bradycardia. The second one is the sympathetic nervous system, which involves the activity of aortic and carotid bodies and arterioles supplying limbs, the skin, the kidneys, and the intestines.

Bradycardia helps to balance the vasoconstriction and the energy used by the heart is reduced, because it is providing fewer organs with blood. As the cardiac output decreases, blood pressure also does. However, the sympathetic nervous system’s response is vasoconstriction. As a result, the delivery of oxygen to less important peripheral tissues is reduced, allowing them to cool down when circulation is restrained and preventing the heart and brain from asphyxia. It happens especially when cold water is involved. Vasoconstriction facilitates the blood movement between the heart and the brain, and consequently the blood pressure increases.

Facial immersion in a bowl of water while breath-holding will have the full diving effect. Stimuli will be captured by the receptors on the face, located in the centres around your temples and nasal area. The cardiovascular centre and the respiratory centre will work together as a response to these stimuli. The first immediate stimulus is the impact of cold water on the face. This will make the cardiovascular centre work as a response, and bradycardia and vasoconstriction will start. In addition, there is no possibility to breathe. This condition will be processed by the respiratory centre and will react causing apnea. When the arterial chemoreceptors send the stimuli to the medulla oblongata, partial oxygen pressure will make drop the heart rate. This is a result of not getting more O_2 and not letting CO_2 out. The biggest drop will happen in this condition.

Breathing with snorkel during facial immersion. As we have the snorkel, no apnea will occur because we are still able to breathe. The stimulus is the impact of cold water in the face, which will trigger the cardiovascular system, causing to drop in the heart rate immediately. The heart will drop significantly.

When holding the breath in the air, only the respiratory centre is involved. Consequently, the respiratory muscles will produce apnea. The heart rate will decrease but not immediately, it will not kick in until partial pressure of oxygen started to drop the heart rate. Not the biggest drop.

When breathing with a snorkel in the air we are not breathing as we normally would but still are, therefore a reduction of oxygen will happen. It will have the same effect as holding the breath in the air but adding a bit of additional dead space in the system.

Breathing normally in the air will not present a big change in the heart rate. Nevertheless, it is not going to be constant and will slightly fluctuate. This is an ordinary phenomenon, and a big drop is not going to happen.

2. Plot a graph of heart rate versus time for each experimental condition

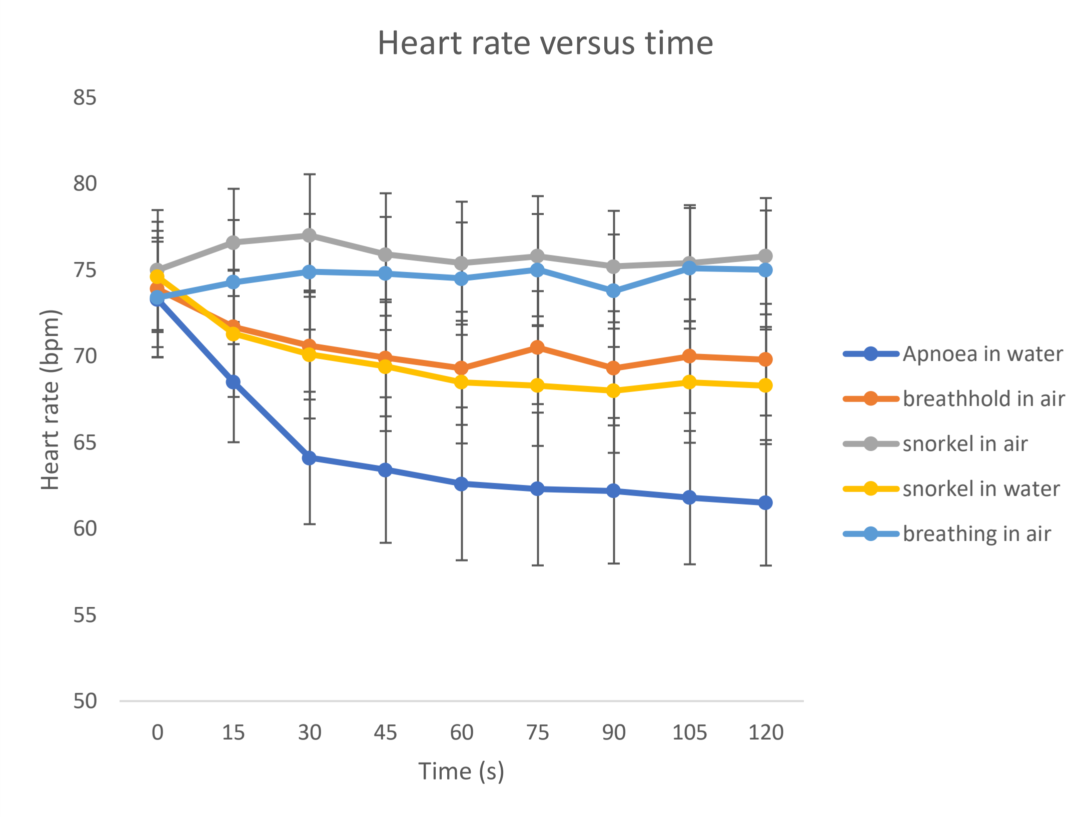

Figure 4: The graph shows the comparison between the mean value of heart rate (bpm) for each condition across all the participants for each time (s) point. This experiment was carried out with ten human subjects. Each person repeated the experiment in five different conditions. Each line represents a specific one under which the experiment was carried. The error bars show the precision of a measurement.

3. Briefly describe the experimental data for each test condition and how it relates to control (breathing in air) and to the other conditions.

For apnoea in water, we get a steady linear decline until 30 seconds, and then it continues decreasing very lightly onwards. The drop of this condition fell dramatically, and for that reason, it experienced the biggest drop out of every other.

Looking at breath-holding in air, from 0 s to 60 s the same gradual decrease that happened in snorkel in water occurred. At the end of this period, the trend of this condition started to fluctuate steadily. A peak occurred at 75s.

The snorkel in water's results experimented a gradually decreased during the entire test. The mean value of the heart rate fell slightly over time. This tendency is markedly similar to holding breath in air. Comparing the mean results of these two conditions to breathing normally in air, the heart rate mean modestly dropped.

For snorkel in air, significant growth can be observed at the beginning of the test. Then it began to slightly fluctuate. The results are significantly similar to breathing air normally, the heart rate mean was roughly higher than the control group.

When breathing air normally, the heart rate remained steady over the period of the experiment. A light fluctuation can be observed.

Subject number 3 maintained a heart rate between 45-55 bpm in all conditions and times. His heart rate remained steady during the entire experiment. This person could be professional in freediving or someone who is used to hold their breath for two minutes in different conditions.

When the face is submerged in cold water, three main triggers are present: the shock of cold water to the face, holding the breath, and resisting the cold temperature.

When the face is submerged in cold water with a snorkel, the main trigger is the impact of cold water in the face. The stimulus will be sensed by the facial nerves and the respiratory and cardiovascular centres will work together to process them. In addition, hydrostatic pressure could have some effect, but the main problem is resisting the cold temperature and the shock of cold water to the face. Breathing is still possible because of the snorkel. However, it is reduced and not as natural since we have dead space.

When breathing in air with a snorkel, the breathing is not as natural as if we were breathing air because of the dead space, however, the respiratory system will not start apnea.

In this experiment, the X is categorical (discrete-time points) and the Y is continuous (the heart rate). T-test can't be used due to having more than two categories. Furthermore, the data points are not independent since the people in each of our time points were the same. For this reason and considering that we got two different explanatory variables (time and the way the heart rate varies over the different conditions), the appropriate statistical test should be a two-way ANOVA.

4. Discuss whether the data fit with your expectations.

Looking at figure 4, the full diving response only happens when there is apnea in water. Although the heart rate slightly drops when holding the breath in air, it is not enough to elicit the full diving response. This observation led to think that apnea alone is not the main force to cause the dive reflex but reinforces the reaction of the medulla oblongata.

Coldwater in addition to apnea makes the biggest drop in the heart rate. The initial stimuli are sensed by the receptors on the face, triggered by the facial temperature and the shock of cold water to the face. This will make the cardiovascular centre work as a response, and bradycardia and vasoconstriction will start. Bradycardia and vasoconstriction start quickly as a result of cardiovascular centre work when the stimulus of the impact of cold water in the face is sensed by the receptors, in this case, the trigeminal cranial nerves.

In addition, there is no possibility to breathe. This condition will be processed by the respiratory centre and will react causing apnea. When the arterial chemoreceptors send the stimuli to the medulla oblongata, partial oxygen pressure will make drop the heart rate. This is a result of not getting more O2 and not letting CO2 out.

5. What other cues could be functioning in the stimulation of the dive response that have not been singled out in the above tests?

Adrenaline could cause the opposite effect and end up accelerating the heart rate. An experiment based on a blood sample would be ideal to measure it. The temperature could be another important factor, the colder the water and air, the bigger the gasps response and impact on the facial nerves.

Part D

1. State hypotheses predicting which condition will produce the strongest grip

Muscle contraction is the force generated by the formation of cross-bridges between actin and myosin filaments. It is the activation of the force-generating mechanism. The degree of overlap between the actin and myosin is what makes effective the contraction and dictates the amount of force a muscle can generate. For this reason, the wrist flexed will produce the strongest grip.

2. Plot a graph of grip strength in each experimental condition

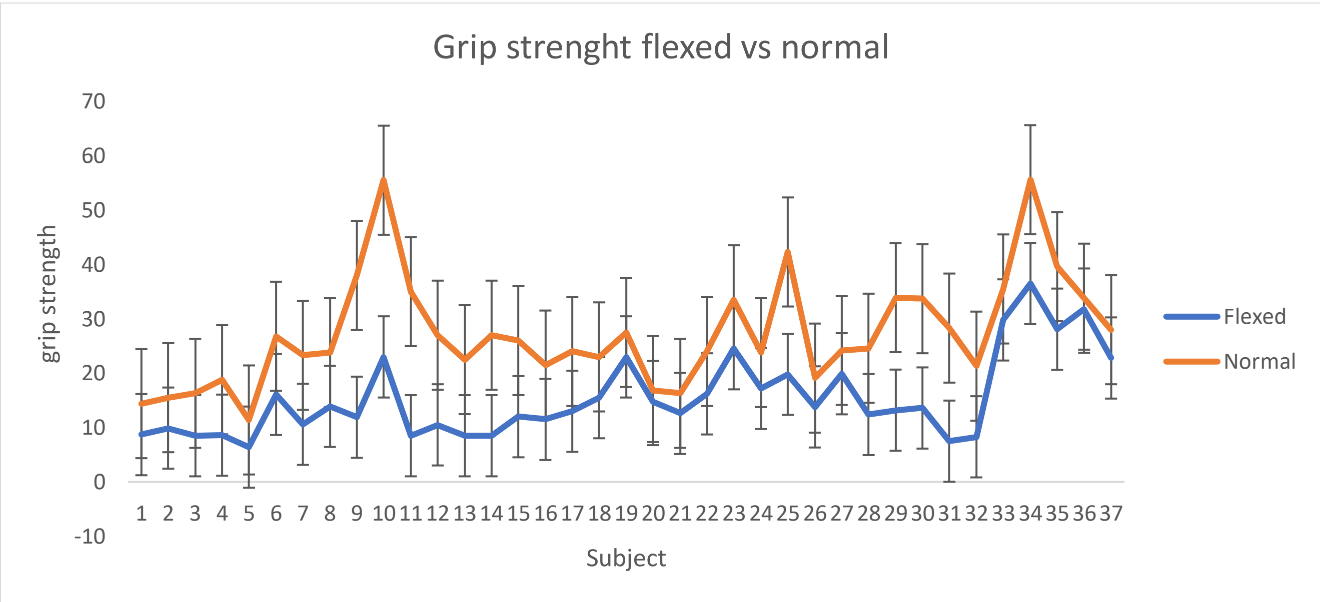

Figure 5: The graph shows the comparison between the grip strength (in kilograms force) in the dominant hand when the wrist flexed and in a normal position without straining. Each line represents a condition. This experiment was carried out with 37 human subjects using a dynamometer. The experiment was repeated three times in both conditions and the final result was the best measurement of the three. The error bars show the precision of a measurement.

3. Perform an appropriate statistical test to find out if grip strength is altered by flexion and report the results in an appropriate format.

The appropriate test is a paired T-test since 2 categories are being compared, but the same individuals participated in both conditions. The data have a normal distribution (Shapiro Wilks: W= 0.922, p= 0.010, n=37). The test statistics results were: 38.0 degrees of freedom, P-value <.001, mean difference 11.7, SE difference 1.20, (14.1-9.24) 95% confidence interval.

4. Discuss the data, the statistical test and the way the experiment was performed

To see if the difference between the grip strength in both conditions is statistically significant, the p-value must be under 0.05. This indicates a 5% of error. The p-value obtained in the test Shapiro-Wilk is 0.010. For this reason, it can be concluded that the subjects had more strength when the wrist is flexed.

In this experiment, the elbow was resting on the bench. This helped to gain strength in the wrist since all the energy was focus on the grip and the elbow had support. Another factor that may contribute to grip strength is age. As the years go by, the body loses strength and there is a disruption in actin and myosin interactions.

To expand the experiment, another interesting study could be taking into consideration different health conditions and the level of physical activity of the subjects. The natural loss of muscle mass because of age is called sarcopenia. This is one of the conditions that affect grip strength since a lot of energy is lost in the muscle mass decrease of the upper body. Besides normal aging, other diseases such as osteoarthritis, rheumatoid arthritis, or tendinitis in the wrists affect directly the grip strength.

However, muscle fatigue could likely contribute to the differences between both conditions in this experiment. This is because the first condition was tested three times in a row, and then the measurements when the wrist was flexed were taken. If the data could be recorded with the same muscle fatigue in each test, maybe a higher difference between the conditions could be observed.

5. What is the difference between passive and active sufficiency and which is operating when the wrist is extended and when it is flexed?

In stretched muscle, only some of the cross-bridges are overlapping so the muscle cannot exert as much force and cannot shorten as effectively. Little contact between the sliding filaments means it is difficult to generate tension. This is called passive insufficiency and it is what happens when the wrist is extended.

When the muscle is fully contracted, all cross-bridges are overlapping. This means there is full contact and no further room to slide so no further tension can be generated. This is called active insufficiency and it is the mechanism that occurs when the wrist is flexed.