# Defining the Benchmark for Optimum Human Ageing

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## Master Cyclists Main Report

**Background**

With an ageing population the necessity to remain physically fit and healthy is essential not only at an individual level but also for society due to the disproportionately large expenditure by the NHS on individuals over the age of 60 years. Currently however we know very little about how the changes that occur within the body in later life are a result of the ageing process itself. This is because many of the studies of ageing are contaminated by the lifestyle factors of people studied. Physical inactivity is known to have negative effects on the body at all ages and will therefore distort the effects of the inherent ageing process on physiological function. We also do not know how much activity is required to remain healthy and age optimally.

To address these issues we measured a wide range of physiological function in master cyclists who exercise well above any threshold of activity required to offset the effects of inactivity. In doing so we can begin to determine exactly which physiological functions decline due to the inherent ageing process and which are likely to be related to inactivity. In addition we can identify the upper limits of physiological function achievable for a given age which it is impossible to do with current published data.

This is the first step in what we hope to be a series of investigations where we would like not only to bring you back in for testing in 5 years' time but also conduct a parallel study on sedentary individuals. From this we will be able to determine exactly how much better off you are compared to the population at large and, assuming your activity levels are similar in the future, how much your function is maintained by your healthy lifestyle.

**Findings**

We finished testing in December 2013 after recruiting 125 cyclists. By the end of the study we had tested 84 men and 41 women. Given the gender distributions in longer distance cycling we had always anticipated this would be the case.

The table below shows the basic characteristic of the subjects in the study split by gender and also by age group.

| | Male | | | | | Female | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age groups | 55-59 | 60-64 | 65-69 | 70+ | All | 55-59 | 60-64 | 65-69 | 70+ | All |
| Number of Subjects | 22 | 24 | 19 | 19 | 84 | 15 | 15 | 7 | 4 | 41 |
| Age (years) | 58 | 62 | 67 | 73 | 64 | 56 | 62 | 67 | 75 | 62 |
| Height (m) | 1.78 | 1.70 | 1.77 | 1.76 | 1.77 | 1.65 | 1.7 | 1.6 | 1.61 | 1.64 |
| Weight (kg) | 77.2 | 76.8 | 72.6 | 74.4 | 75.4 | 61.5 | 60.4 | 57.8 | 57.1 | 60 |
| BMI (kg.m$^2$) | 24.5 | 24.7 | 23.2 | 24.1 | 24.2 | 22.6 | 22.1 | 21.9 | 22 | 22.2 |
| Heart Rate (bpm) | 53 | 54 | 52 | 60 | 54 | 58 | 60 | 59 | 59 | 59 |
| SBP (mmHg) | 127 | 134 | 135 | 140 | 134 | 127 | 129 | 125 | 138 | 129 |
| DBP (mmHg) | 69 | 70 | 68 | 71 | 70 | 68 | 66 | 68 | 72 | 68 |
| Years Cycling | 22.4 | 28 | 27 | 37 | 28.1 | 15.6 | 25 | 16 | 45 | 21.8 |
| Monthly Distance | 764 | 635 | 803 | 731 | 728 | 628 | 611 | 482 | 622 | 596 |
| Time spent performing activity | | | | | | | | | | |
| Light (min/day) | 203 | 213 | 236 | 221 | 218 | 224 | 232 | 261 | 237 | 234 |
| Moderate (min/day) | 68 | 75 | 71 | 67 | 70 | 74 | 73 | 77 | 74 | 74 |
| Hard (min/day) | 27 | 28 | 26 | 26 | 27 | 33 | 31 | 28 | 26 | 31 |
| Very Hard (min/day) | 71 | 85 | 96 | 79 | 82 | 100 | 91 | 71 | 120 | 94 |

A number of points can be observed from the table:

1. There appears to be little effect of age on any of the variables measured
2. On the whole the males tend to have higher values than females
3. The weights recorded are lower than expected for a similar age group
4. Body mass index (BMI) values indicate that on average the group is in the normal weight category (19-25 = normal, 25-30 = overweight, >30 = obese)
5. Resting heart rates are lower than would typically be expected in the general population (60 – 80 bpm) likely due to the high physical fitness of the group
6. Interestingly systolic blood pressure (SBP) is slightly higher than would be typically expected while diastolic blood pressure (DBP) is a little lower. Ideal values are suggested to be 120/80mmHg whereas we found values of 134/70 and 129/68 for males and females respectively. Given the low DBP values there is little concern with a slightly elevated SBP (which is still well below values that would be expected in someone with hypertension)
7. The distances cycled per month are high and do not appear to change with age
8. The time spent performing moderate/hard/very hard activity is well above that previously reported in the population at large (typically less than 30 mins as opposed to 150-170mins)

The percentage body fat recorded for was well below that expected for a similar age group. This can be clearly seen in figure 1 where the average body fat values for males (blue line) and females (red line) is plotted on top of the data obtained. Body fat is generally though to increase with age. We however found no relationship between age with the values obtained similar to that of 20 - 40 year olds.

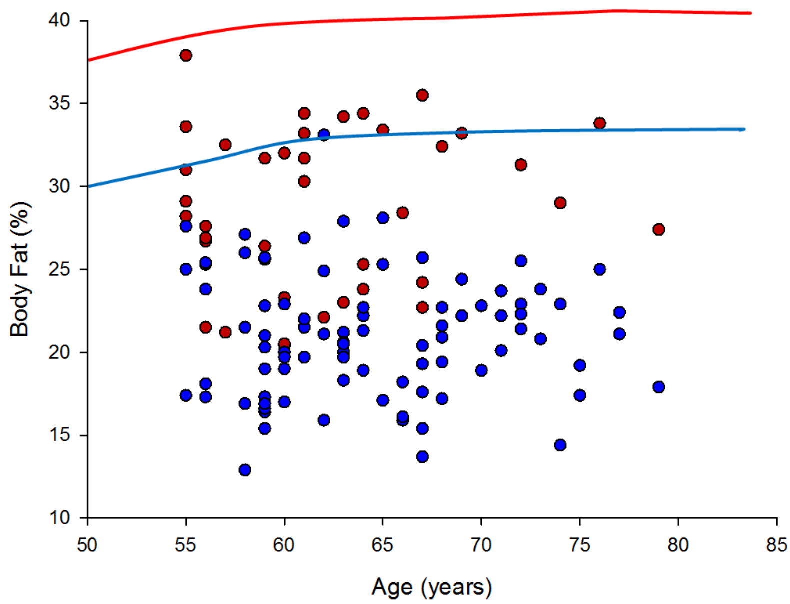



**Figure 1Body fat values obtained for males (blue) and females (red). Lines indicate average values obtained for the general population of the same age range.**

*Bone Strength*

Figure 2 shows the bone strength recorded for the whole body, spine and the hip in men and women (blue and red respectively). It was found that the strength of the bone in the lower back decreased with age in both men and women, while whole body bone strength also declined in men.

The bone strength of men is significantly greater than women. Also, typically declines in bone strength are expected to be greater in women due to changes in hormone levels after the menopause.

Comparison of the values obtained in the cyclists studied to the population at large (blue and red lines overlaid on figure) indicate that values obtained are similar to that normally expected. Bone growth, and therefore strength, is stimulated by placing loads on the skeletal structure. As cycling is a non-weight bearing activity and does not exert high loads on the skeleton this likely accounts for the similar bone strength between the general population and the cyclists studied. Ideally for the maintenance of bone strength weight bearing activities should be performed such as walking and running although other lifestyle and diet modifications can be made.

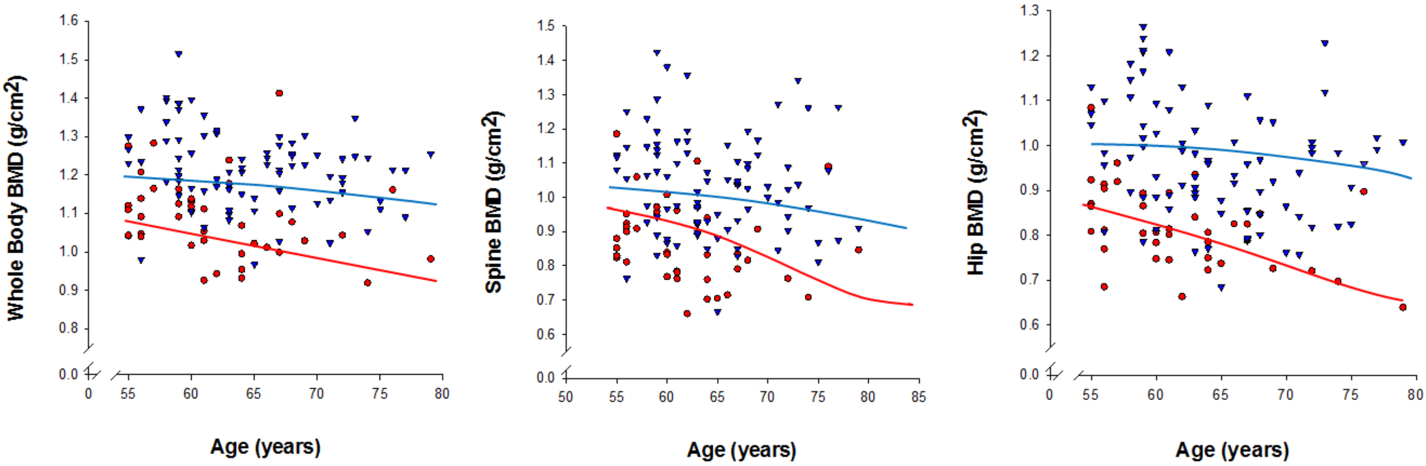



**Figure 2 Bone strength recorded of the whole body, spine and hip in males (blue) and females (red). The overlaid lines indicate the average values obtained for the general population.**

### $\dot{V}O_{2max}$

$VO_{2max}$ is essentially the maximum amount of oxygen your body can take up and use when exercising at maximal effort. It provides an indicator of your capacity to use aerobic (using oxygen) mechanisms to provide energy during exercise and is considered the best indicator of a person's physical fitness.

Although $\dot{V}O_{2max}$ declined with age the relationship between age and $\dot{V}O_{2max}$ we found was not very strong. Figure 3 shows the values recorded during the study. Again the males have higher recorded values than females which is typically expected due to the difference in body composition between genders. Every one of the 125 people tested in the current study had higher values of $\dot{V}O_{2max}$ than would be expected in the general population (right hand graph of figure 3 showing results expressed as a percentage of age and sex predicted values).

The values we have recorded are very high for the age group we are studying. This indicates that you are all extremely fit, much more than would typically be expected. This is an extremely important finding particularly given that some of you only took up cycling relatively recently. This data highlights that irrespective of age you can always improve your health and fitness by taking up exercise and that it is possible to perform what some people would classify as "extreme" amounts of activity well into later life.

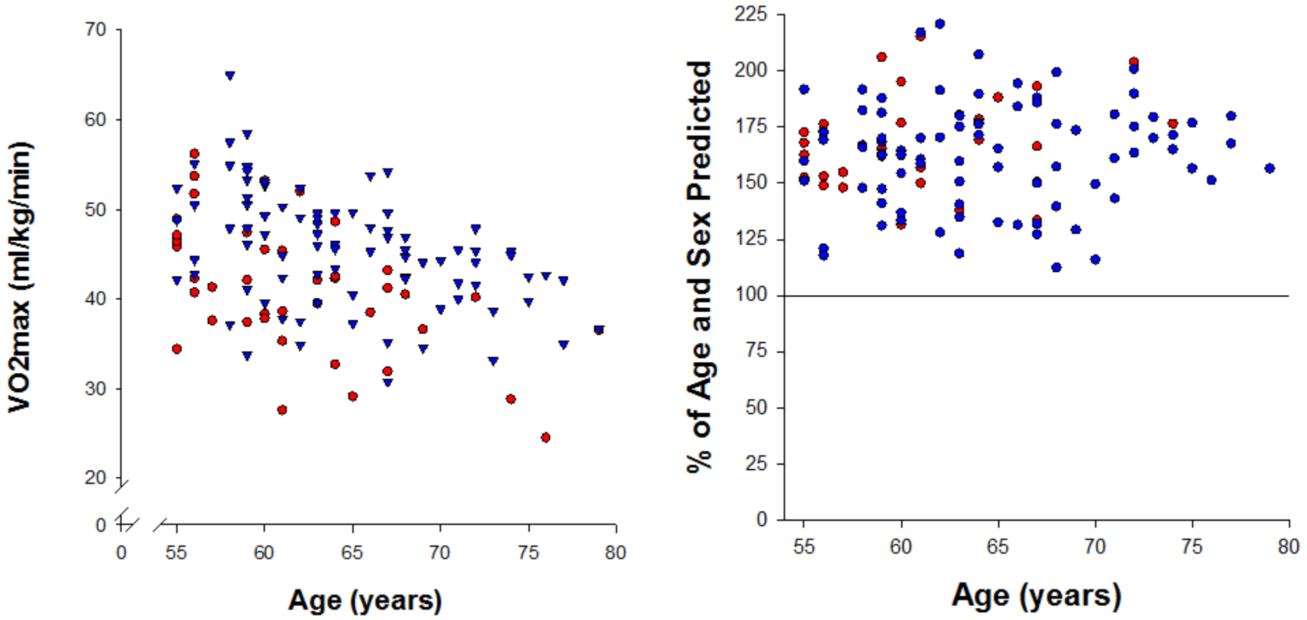



**Figure 3 V̇O2max for men (blue) and women (red). The left figure shows the values we recorded during the study. The right figure shows the same data expressed as a percentage of the age and sex predicted normal values.**

To put the results we obtained for you into perspective the tables below give the values of $\dot{V}O_{2max}$ that are used to classify fitness levels based on age and gender. The lowest values that may be observed are around 10 ml/kg/min which would be found in people with heart problems. Elite endurance athletes (cross-country skiers and cyclists) have been reported to have values of up to 80-90 ml/kg/min.

**Male** (values in $ml.kg^{-1}.min^{-1}$)

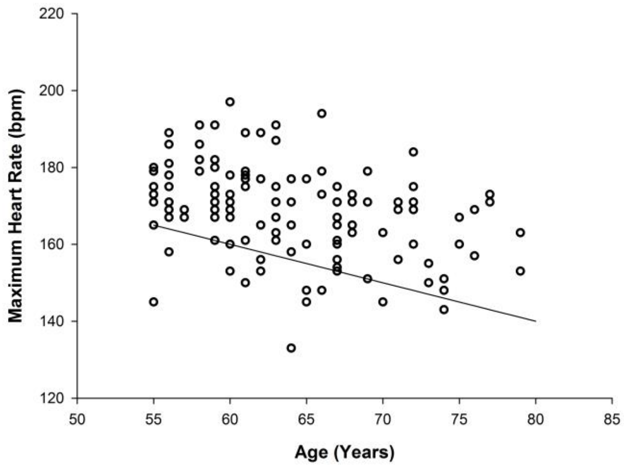
| Age | Very Poor | Poor | Fair | Good | Excellent | Superior |
|---|---|---|---|---|---|---|
| **20-29** | <33.0 | 33.0 - 36.4 | 36.5 - 42.4 | 42.5 - 46.4 | 46.5 – 52.4 | >52.4 |
| **30-39** | <31.5 | 31.5 - 35.4 | 35.5 - 40.9 | 41.0 - 44.9 | 45.0 – 49.4 | >49.4 |
| **40-49** | <30.2 | 30.2 - 33.5 | 33.6 - 38.9 | 39.0 - 43.7 | 43.8 - 48.0 | >48.0 |
| **50-59** | <26.1 | 26.1 - 30.9 | 31.0 - 35.7 | 35.8 - 40.9 | 41.0 - 45.3 | >45.3 |
| **60+** | <20.5 | 20.5 - 26.0 | 26.1 - 32.2 | 32.3 - 36.4 | 36.5 - 44.2 | >44.2 |

**Female** (values in $ml.kg^{-1}.min^{-1}$)

| Age | Very Poor | Poor | Fair | Good | Excellent | Superior |
|---|---|---|---|---|---|---|
| **20-29** | <23.6 | 23.6 - 28.9 | 29.0 - 32.9 | 33.0 - 36.9 | 37.0 - 41.0 | >41.0 |
| **30-39** | <22.8 | 22.8 - 26.9 | 27.0 - 31.4 | 31.5 - 35.6 | 35.7 - 40.0 | >40.0 |
| **40-49** | <21.0 | 21.0 - 24.4 | 24.5 - 28.9 | 29.0 - 32.8 | 32.9 - 36.9 | >36.9 |
| **50-59** | <20.2 | 20.2 - 22.7 | 22.8 - 26.9 | 27.0 - 31.4 | 31.5 - 35.7 | >35.7 |
| **60+** | <17.5 | 17.5 - 20.1 | 20.2 - 24.4 | 24.5 - 30.2 | 30.3 - 31.4 | >31.4 |

**Table 2 Classification of fitness based on $\dot{V}O_{2max}$**

The figure below shows the maximum heart rates recorded for everyone during testing as well as the predicted maximum heart rate. The majority of values recorded exceeded the predicted maximal heart rate. There are a number of reasons this may be the case; 1) prediction equations are derived from the general population most of whom are not used to exercising at maximal effort and therefore probably don't reach a true maximum heart rate, 2) there is a lot of variation in heart rates of people of the same age (as can be clearly seen from the figure) this means that it is impossible to accurately predict maximum heart rate. For those people interested in using their heart rate to guide the intensity of the exercise they perform it is much better to use the actual value recorded when we tested you rather than any predicted values.




*Strength and Power*

Figure 4 shows the values obtain for your knee extensor strength (Quadriceps strength measured when you were strapped into the chair and asked to kick forward as hard as you could), explosive power (measured on the exercise bike I made you do a 5 s sprint on) and your hand grip strength.

The strength of the quadriceps we recorded was similar to that of other studies on master athletes. Compared to the general population you are a little bit stronger. We wouldn't necessarily expect to see significantly greater strength of the quadriceps between endurance athletes and the general population the main reason being that it is not advantageous to have big strong muscles rather endurance activities need muscle that can keep going for a long time which the strong muscle fibres can't (see section below about muscle biopsy results). What is interesting with the current results is that you typically expect to see rapid declines in strength between the ages of 60 and 70 years which does not happen in the current study suggesting the exercise you do is enough to maintain your strength.

Being able to generate sufficient power is essential for older individuals. Basic tasks like getting out of a chair or climbing a flight of stairs require fairly high power outputs. It is therefore very encouraging that the values recorded are well above what is expected and do not show any clear sign of decline with age. The level of exercise you do, and particularly any time you have to push off on your bike or climb a hill, has probably contributed to the high power outputs we recorded. This is also related to the findings we have for the muscle samples we took which will be discussed later.

Hand grip strength is a key predictor of disability with old age and is something that is good to try and maintain. The values we recorded again are above what would be expected for the general population (averages are around 250N for women and 450N for men at age of 50 and decline at a rate of 1-2% per year).

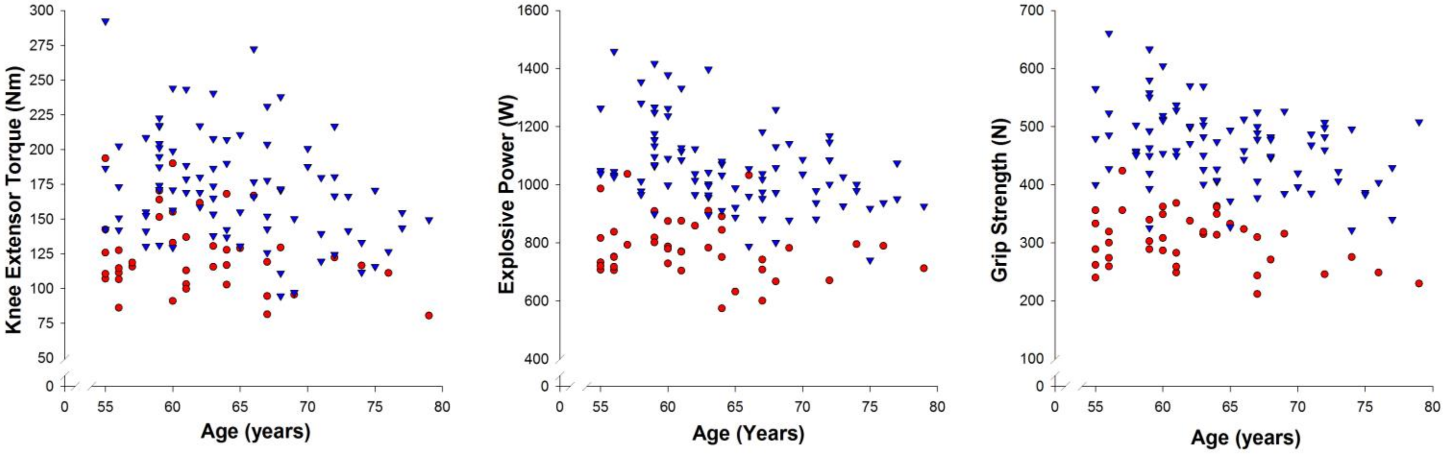



**Figure 4 Quadriceps (left) and grip (right) strength. The middle figure shows the maximum instantaneous power that was generated while cycling (the very first couple of pedal revolutions while sprinting)**

For the most part the males have higher values for strength, power and $\dot{V}O_{2max}$ than females. The main reason for this is that men are generally bigger and have slightly different fat distributions than females. As we measured the amount of fat everyone in the study had we were able to account for this difference. When we did we found that there was no difference between men and women in strength, power or $\dot{V}O_{2max}$. Essential what this means is that if we were to look at a single muscle fibre from a man and woman there would be absolutely no difference between them. Predominantly it is only the greater amount of muscle men have that results in the difference between males and females.

*Muscle Biopsies*

From the 125 subjects tested 90 allowed us to take a muscle sample; much more than we had initially expected. We have currently analysed about three-quarters of the samples and are currently working through the remainder. The findings we have so far are extremely interesting and likely account for the results obtained for your strength and power.

Basically there are two types of muscle fibres: Fast and Slow. Fast fibres are stronger and fast contracting but fatigue very quickly. Slow fibres on the other hand are weaker, slower contracting but fatigue resistant. Ideally what you want to perform endurance exercise are therefore more slow fibres, the only time you would likely recruit fast fibres when cycling is if you are hill climbing (or sprinting).

Typically as people get older the number of fibres they have decrease (both fast and slow). The size of slow fibres tends to stay the same whereas fast fibres become much smaller. This loss in size and number, particularly of fast fibres, results in strength and power declining with age.

In the current study we found that on average 69% of your muscle fibres are slow fibres. This is much higher than that typically observed of 50-58% (shaded area of Figure 5). Endurance athletes would often be reported as having higher numbers of slow fibres which is extremely beneficial for that type of exercise. What is more interesting about the samples we took is the size of the fibres. Unsurprisingly we found no change in the size of the slow fibres however we also found no change in the size of the fast fibres. Figure 5 shows one of the pictures we determined muscle fibre size from (black fibres are fast and white fibres are slow). There is no difference in the size and shape of the fast fibres compared to the slow. It is this maintenance of fast fibre size which likely accounts for the significantly higher power outputs we recorded as these fibres are the most important for generating power. This is a novel finding of the study as it is widely accepted that fast fibres size declines with age which is clearly not the case in the current study.

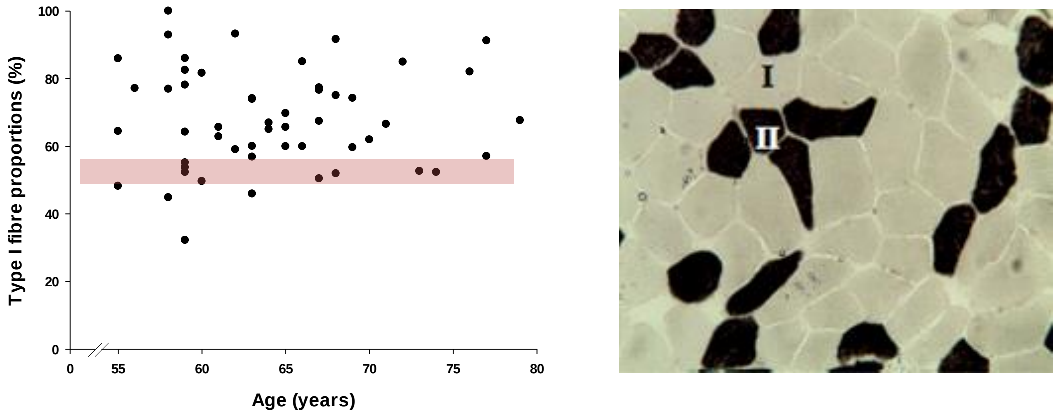



**Figure 5 Fibre proportions and representative picture of muscle fibre where slow (white) and fast (black) fibres of similar shapes and sizes can be seen.**

## Summary

Overall, and as expected, the cyclists studied have much better physiological function than would be expected in the general population. In addition even though some variables do decline with age the association we found between them and age was weak. By exercising it is likely that you have been able to prevent or reduce the impact of ageing on physiological function (in essence maintaining function at a level similar to that of someone 20 years younger). What these findings suggest is that it is not ageing per se that causes function to decline as you get older but rather the effects of inactivity combined with ageing.

The only way to get a true understanding of how function changes with age we need to test people that exercise a number of times as they get older. As such we hope, if you are willing, to bring you back for testing in 4-5 years' time which would give us the ideal study to understand ageing. When we started this study we expected you to perform better than the general population however you exceeded our expectations by quite some way with some values we obtained for you being similar to that of an average 20-30 year old. This shows how much keeping active can benefit you and that age should never be a barrier to being more active.

Again we would like to thank you for participating in the study and we hope that you will be willing to come back and do it again at some point in the future. We fully intend to keep you informed with the findings of the study and will send you copies of all the publication we have from it the first of which will be completed soon.