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Maximal aerobic power and anaerobic capacity in cycling across the age spectrum in male master athletes

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Short title: Maximal aerobic power and anaerobic capacity in aging cyclists

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1 **Abstract**

2 *Purpose* We analysed the best performance times of master cycling athletes in the 200 m – 3000 m track competitions
3 to estimate the decay of maximal aerobic power (*MAP*) and of anaerobic capacity (*AnS*) with aging.

4 *Methods.* In various decades of age (30-80 yy), *MAP* and *AnS* were estimated by using an iterative procedure as the
5 values that minimise the difference between: i) the metabolic power ($\dot{E}(t)$) necessary to cover a given distance (*d*) in
6 the time *t* and; ii) the maximal metabolic power ($\dot{E}_{max}(t)$) maintained at a constant level throughout the competition.

7 *Results* *MAP* started decreasing at 45 years of age. Thereafter, it showed an average per-cent rate of decrease of about
8 16 % for decade, as previously shown in other classes of master athletes. Also *AnS* seemed to decay by about 11 %
9 every 10 years from the second part of the fifth decade.

10 *Conclusions* The decay of *MAP* occurred in spite of the active lifestyle of the subjects and it may be attributed to the
11 progressive impairment of maximal O₂ delivery and/or of peripheral O₂ utilisation. The loss of *AnS* might derive from
12 the progressive loss of muscle mass occurring after the fifth decade of life, to the progressive qualitative deterioration of
13 the anaerobic energy yielding pathways or to the lower capacity of MN recruitment during maximal efforts. The
14 proposed approach may be applied to other types of human locomotion of whom the relationship between performance
15 *t* and $\dot{E}(t)$ is known.

16

17 **Key words:** master athletes; maximal aerobic power; anaerobic capacity; cycling; ageing

18

19 **List of specific abbreviations**

- 20 A : frontal area of the subject riding the bike, m^2
- 21 AnS : Anaerobic capacity, kJ
- 22 $[ATP]$: intramuscular adenosine-tri-phosphate concentration, $mM\ kg^{-1}$
- 23 BPT : Best Performance Time, s
- 24 C : energy cost of human locomotion, $kJ\ km^{-1}$, $J\ m^{-1}\ kg^{-1}$
- 25 $C_{c,a}$: average energy cost of cycling during the acceleration phase for a stationary start, $kJ\ km^{-1}$, $J\ m^{-1}\ kg^{-1}$
- 26 C_c : energy cost of cycling, $kJ\ km^{-1}$, $J\ m^{-1}\ kg^{-1}$
- 27 C_m : rolling resistance coefficient
- 28 C_x : drag coefficient
- 29 d : distance, m
- 30 $E_{acc,a}$: amount of metabolic energy spent during the acceleration phase, kJ
- 31 E_{Aer} : percent contribution of aerobic energy sources to a given effort, %
- 32 E_{Ans} : percent contribution of anaerobic energy sources to a given effort, %
- 33 $\dot{E}(t)$: Metabolic power required to cover a given distance d as a function of the time in human locomotion, kW
- 34 $\dot{E}_c(t)$: Metabolic power required to cover a given distance d as a function of the time in cycling, kW
- 35 $\dot{E}_{max}(t)$: Maximal metabolic power available to the athlete as a function of the time of effort, kW
- 36 η_c : apparent mechanical efficiency of cycling
- 37 g : acceleration of gravity, $9.81\ m\ s^{-2}$
- 38 HR_{max} : maximal hear rate, beats per minute
- 39 $[La]_b$: blood lactate concentration, peak lactate concentration, mM
- 40 M_t : overall mass (subject plus frame), kg
- 41 MAP : Maximal Aerobic Power, kW
- 42 MAP_{IH} : Maximal Aerobic Power calculated from the metabolic power maintained by during best hour unaccompanied
- 43 performance, kW
- 44 $[PCr]$: intramuscular phosphocreatine concentration, $mM\ kg^{-1}$
- 45 ρ : air density, $kg\ m^{-3}$
- 46 t_e : time of exhaustion, s
- 47 τ : time constant of the mono-exponential increase of muscular oxygen uptake as a function of time of exercise, s
- 48 s : speed of locomotion, $m\ s^{-1}$
- 49 $\dot{V}O_{2max}$: maximal oxygen uptake, $L\ min^{-1}$, $mL\ min^{-1}\ kg^{-1}$

50 **Introduction**

51 Aging is the result of a continuous, irreversible process that evolves during the lifespan of most, if not all organisms.
52 From a biological point of view, the negative aspects of aging result from the accumulation of damage and structural
53 modifications leading to the progressive impairment of several physiological functions. Among them, the decay of
54 exercise capacity is of paramount importance, as it progressively limits the daily life autonomy and restricts physical
55 activity in the aging subjects.

56 Maximal aerobic power (*MAP*) – related to maximal oxygen uptake ($\dot{V}O_{2max}$) – is one of the most important
57 physiological variables correlated with endurance and maximal performances and it is also a predictor of cardiovascular
58 mortality (Lakka et al. 2002). After the peak in young adult age, *MAP* has been described to decay by about 10 % per
59 decade in the general population after the age of 30 (Åstrand 1973; Dill et al. 1967; Maharam et al. 1999; Marti and
60 Howland 1990; Marcell et al. 2003; Robinson 1938; Rogers et al. 1990; Trappe et al. 1996), even though we do not
61 know exactly at which age this decay becomes evident.

62 Exercise capacity, however, may also be limited, especially during very high intensity and supra-maximal efforts, by
63 the amount of energy obtained from the anaerobic energy stores, i.e. the anaerobic capacity (*AnS*). In this regard, the
64 data describing the progressive drop of *AnS* with aging are rather scanty (Marti and Howland 1990). If we assume that it
65 is mainly related to the muscle mass, however, we may surmise that it progressively decays in connection with a
66 noticeable loss in the relative amount of muscle mass, which is progressively occurring after the fifth decade, i.e. 50
67 years-of-age (Janssen et al. 2000).

68 The rate of decay of *MAP* and *AnS* with age might be indirectly evaluated by analyzing the maximal speeds
69 achieved by master athletes in different decades of age (Rittweger et al. 2009; Wiswell et al. 2001; Zamparo et al.
70 2012). For instance, the decline of endurance performance with age has been primarily ascribed to the progressive
71 reduction of *MAP* and of the lactate threshold (Tanaka and Seals 2008). Conversely, as aging has been described to be
72 paralleled by significant decays of anaerobic capacity and anaerobic power even in master athletes (Gent and Norton
73 2013), also best performances over shorter distances are likely bound to decrease with age. Other important factors
74 affecting performances, such as exercise economy in the terrestrial forms of human locomotion, seems to be unaffected
75 by aging (Tanaka and Seals 2008).

76 This analysis, however, could be further refined. In the recent past, several theoretical models to predict best
77 performances in human locomotion - running and cycling and swimming, *e.g.* - have been proposed and tested (Capelli
78 et al. 1998; di Prampero et al. 1993; Olds et al. 1993; Toussaint and Hollander 1994). In general, these models are based
79 on the fact that in human locomotion the metabolic power $\dot{E}(t)$ required to cover a given distance d in the time t is set
80 by the product of the energy cost of the locomotion at stake (C) and the speed ($v = d t^{-1}$), where C is the amount of

81 metabolic energy spent to cover one unit of distance (di Prampero 1986). C of several forms of locomotion on land has
82 been described in a quantitative fashion as a function of the terrain incline and type, the speed, the anthropometrical
83 features of the subjects, the technical characteristics of the mean of locomotion, the environmental conditions, etc. etc.
84 (Capelli et al. 1998; di Prampero et al. 1993; Minetti et al. 2002; Olds et al. 1993). Therefore, $\dot{E}(t)$ required to cover a
85 given distance (d) as a function of t in forms of locomotion such as running and cycling can be individually determined,
86 provided that we measure selected physiological and anthropometrical parameters of the subject and obtain the other
87 essential parameters entering the equations.

88 Of course, the best performance time (BPT) over any given d satisfies also the equality $\dot{E}(t) = \dot{E}_{max}(t)$, where the
89 latter is the maximal metabolic power that is produced and maintained at a constant level by the athlete from the start of
90 the competition to the end. \dot{E}_{max} is a decreasing function of t and mainly depends upon the subject's MAP and AnS
91 (Capelli 1999; di Prampero et al. 1993). So, provided the relationship between C and s and the subject's MAP and AnS
92 are known, the best BPT over any given distance can be estimated by finding, through computerized iterative
93 procedures, the value of t that solves the equality $\dot{E}_{max}(t) = \dot{E}(t)$.

94 This approach, however, can be also reversed. In cycling, for instance, by knowing the BPT over several distances
95 of a given athlete, and by knowing his/her anthropometrical characteristics, the environmental conditions prevailing
96 during the competition and the technical features of the frame, we may theoretically calculate backwards an athlete's
97 MAP and AnS . Of course, this procedure, once applied to subjects of different ages, would allow us estimate the
98 changes of MAP and AnS across the age spectrum without the interference of the additional confounding effects of
99 disuse, detraining and sedentary life style, since master athletes keep training in view of participating to highly
100 demanding competitions. Track cycling performances of Master Athlete over distances ranging from 200 to 3000 m
101 seem to be particularly appropriate for this sort of analysis because: i) the shortest distances are covered performing
102 high intensity exercises (< 2 minutes) where anaerobic processes dominate; ii) the longest distance – 3000 m is covered
103 in less than 7 minutes, i.e. within an interval of time during which the cyclist is likely able to exploit throughout the
104 effort a fraction of MAP equal to 1 (Péronnet and Thibault 1989). Therefore, by applying this line of reasoning, the
105 backward resolution of the model may allow us estimate the evolution of MAP and AnS across the age spectrum without
106 the interference of the effects derived from assuming a sedentary life - style or the presence of diseases. In addition,
107 since it has been suggested that the rate of decay of running performances in the shorter distances may be significantly
108 different from the one of the longer events (Baker et al. 2003; Fung and Ha 1994; Gent and Norton 2013; Moore 1975),
109 this analysis may also unveil whether the decrease of MAP and AnS as a function of the age is similar or diverge.

110 In summary, the aim of this paper consists in estimating the changes of MAP and AnS in men master athletes
111 participating in track cycling competitions across a spectrum of ages ranging from 40 to 80 years. MAP and AnS will be

112 indirectly estimated i) by using *BPT* obtained by the master athletes over several distances competing in international
 113 events and classified in different classes of age and; ii) by finding the corresponding *MAP* and *AnS* values that solve the
 114 equality between \dot{E} (*BPT*) and \dot{E}_{\max} (*BPT*). This will also help understand whether the deterioration rates of these
 115 parameters with age are different.

116

117 **Methods**

118 *Metabolic power requirement in track cycling*

119 The metabolic power required covering as function of time a given distance in track cycling has been calculated
 120 according to the approach proposed by Capelli (Capelli et al. 1998; Capelli 1999).

121 The total overall energy cost per unit of distance in track cycling (C_c) on flat terrain in absence of wind is given by
 122 the sum of three terms:

123

$$124 \quad C_c = C_{rr} M_t g + k' s^2 + 0.5 M_t s^2 d_{\text{tot}}^{-1} \eta_c^{-1} \quad (1,$$

125

126 where g is the acceleration due to gravity (m s^{-2}), s (m s^{-1}) is the air speed, which in still air can be considered
 127 identical to the ground speed, and the other terms are defined here below.

128 The first term ($C_{rr} M_t g$) is the metabolic energy spent against rolling resistance; it is proportional to the product of
 129 the overall mass M_t (75 kg body mass, 10 kg frame) and to the coefficient C_{rr} , which is the amount of energy spent over
 130 a unit of distance and per unit of overall mass against frictional forces. The value of this term depends upon the
 131 characteristics of the tires and of the terrain and, for $M_t = 85$ kg and for $C_{rr} = 0.031 \text{ J m}^{-1} \text{ kg}^{-1}$ (Capelli et al. 1999),
 132 amounts to 25.8 J m^{-1} .

133 The second term ($k' v^2$) is the metabolic energy spent per unit of distance against air drag ($C_{c,a}$, J m^{-1}); it is
 134 proportional to the square of the air speed (s) and to a constant k' which, in turn, is described by (Capelli et al. 1999):

135

$$136 \quad k' = 0.5 C_x \rho A \eta_c^{-1} \quad (2.$$

137

138 C_x in Eq. 2 is the dimensionless drag coefficient, which can be considered as a constant at the range of speeds
 139 investigated (Pugh 1974); it was set equal to 0.58 for a cyclist riding a traditional racing bicycle in a fully dropped
 140 position (Capelli et al. 1993). The air density ρ , for an air temperature of 20°C and a barometric pressure of 760 mmHg,
 141 disregarding the contribution of water vapor, amounts to 1.2047 kg m^{-3} ; A is the frontal area of the subject riding the
 142 bicycle, and amounts to $\approx 0.43 \text{ m}^2$ for a subject of 175 cm in stature and 75 kg body mass (Capelli et al. 1998). This

143 yields product of C_x times A of 0.249 m^2 (Garcia-Lopez et al. 2008). With an overall efficiency of cycling, η_c , equal to \approx
 144 0.22 (Seabury et al. 1977), k' turns out to be $0.68 \text{ J s}^2 \text{ m}^{-1} \text{ m}^{-2}$.

145 The speed becomes constant only after the acceleration phase has been completed: therefore, $C_{c,a}$ in the constant
 146 speed phase can be calculated as indicated by Olds and colleagues (1993) as:

147
 148
$$C_{c,a} = 0.68 \text{ s}^2 (d_{tot} - d_{acc})d_{tot}^{-1} = 0.68 \text{ s}^2 (1 - d_{acc}/d_{tot}) \quad (3,$$

149
 150 where d_{tot} and d_{acc} represent: (1) the total distance, and (2) the distance covered to accelerate from zero to the
 151 constant speed, assumed to be equal to 100 m (Olds et al. 1993).

152 Since the metabolic energy spent against drag depends on the instantaneous speed, $C_{c,a}$ during the acceleration phase
 153 is lower than that applied to the second part of the competition covered at constant speed. The overall value of $C_{c,a}$ may
 154 be corrected for the initial acceleration phase (100 m long) as follows. First, the total amount of metabolic energy spent
 155 against drag during the acceleration phase ($E_{acc,a}$, J) may be calculated as:

156
 157
$$E_{acc,c} = 0.68 \text{ s}^2 d_{acc} 0.5 \quad (4,$$

158
 159 where $E_{acc,a}$ is the mean of the product of $C_{c,a}$ ($= 0.68 \text{ s}^2$) times d_{acc} , calculated assuming that the acceleration was
 160 constant over d_{acc} (Olds et al. 1993). Then, the contribution of $E_{acc,a}$ to the overall value of $C_{c,a}$ is calculated by dividing
 161 $E_{acc,a}$ by the total distance d_{tot} . After some simplifications, the following equation is derived (Capelli 1999):

162
 163
$$C_{c,a} = 0.68 \text{ s}^2 (1 - d_{acc}/d_{tot}) + 0.68 \text{ s}^2 d_{acc}/d_{tot} 0.5 \quad (5.$$

 164
$$= 0.68 \text{ s}^2 (1 - 0.5 d_{acc}/d_{tot})$$

165
 166 The third term in Eq. 1 ($0.5 M_t s^2 d_{tot}^{-1} \eta_c^{-1}$) represents the metabolic energy spent by the cyclist to accelerate the
 167 overall mass M_t from a stationary start to the final speed s . Thus, if $M_t = 85 \text{ kg}$ and assuming $\eta_c = 0.22$ (Capelli et al.
 168 1993; Seabury et al. 1977), the total metabolic requirement per unit distance in track cycling (C_c , J m^{-1}) is described by:

169
 170
$$C_c = 25.8 + 0.68 \text{ s}^2 (1 - 0.5 d_{acc}/d_{tot}) + 193.2 \text{ s}^2 d_{tot}^{-1} \quad (6.$$

171
 172 The overall metabolic power requirement necessary to progress at the speed v in cycling ($\dot{E}_c = C_c s$) is given by:

173

174 $\dot{E}_c = 25.8 s + 0.68 s^3 (1 - 0.5 d_{acc}/d_{tot}) + 193.2 s^3 d_{tot}^{-1}$ (7.)

175

176 Since in any track competition the distance d_{tot} is fixed, $d_{tot} t^{-1}$ can be substituted for s . As a consequence, Eq. 7 can
 177 be finally rearranged to obtain \dot{E}_c as a function of the time necessary to cover the distance d_{tot} :

178

179 $\dot{E}_c = 25.8 d_{tot} t^{-1} + 0.68 d_{tot}^3 t^{-3} (1 - 0.5 d_{acc}/d_{tot}) + 193.2 d_{tot}^2 t^{-3}$ (8.)

180

181 *Maximal metabolic power*

182 For competitions lasting less than 420 s (Péronnet and Thibault 1989), the maximal metabolic power (\dot{E}_{max}) a given
 183 subject can sustain at a steady level throughout the effort is a decreasing function of the exhaustion time (t_e) (Capelli et
 184 al. 1993; di Prampero et al. 1993) and it may be appropriately described as:

185

186 $\dot{E}_{max} = AnS t_e^{-1} + [MAP - MAP \tau (1 - e^{-t_e \tau^{-1}}) t_e^{-1}]$ (9,

187

188 where AnS and MAP have been already defined and τ is the time constant of the mono - exponential time course
 189 with which MAP is attained at the onset of the effort.

190 The third term arises from the fact that at the onset of exercise $\dot{V}O_{2max}$ is not attained instantaneously, but with a
 191 time constant τ . Hence, the average aerobic power up to the time t_e is given by the quantity in square brackets, i.e. it is
 192 reduced below MAP by an amount equal to the oxygen deficit incurred up to t_e $MAP \tau (1 - e^{-t_e \tau^{-1}})$ divided by the time
 193 t_e itself. The first and third terms of Eq. 9 become progressively smaller with increasing values of t_e . So, Eq. 20 shows
 194 that for long-term exercise, the maximal sustainable metabolic power is essentially set by the subject's $\dot{V}O_{2max}$ and by
 195 the fraction of $\dot{V}O_{2max}$ that can be maintained throughout the effort. As the time of the exercise becomes shorter, the
 196 contribution of the anaerobic energy stores to the overall metabolic power becomes progressively greater because, with
 197 decreasing t_e : (1) the first term of Eq. 9 increases hyperbolically and; (2) the amount by which the oxygen deficit affects
 198 (negatively) the actual average aerobic power becomes larger.

199

200 *Resolution of the model, data analysis and statistics*

201 For any given BPT obtained over a given distance, \dot{E}_c (Eq. 8) required to cover d_{tot} as a function of BPT and \dot{E}_{max} (BPT)
 202 (Eq. 9) must be equal: the record time corresponds to the unique condition wherein the required and the maximal
 203 available power are identical. Provided we have a sufficient numbers of BPT s over different distances, we can calculate

204 the values of MAP and AnS that minimize the differences between the couples of \dot{E}_c and \dot{E}_{max} on the various distances. In
 205 practice, an iterative procedure that implements the so-called Marquardt-Levenberg method for solving non linear
 206 regression parameters (GraphPad Prism version 6.00 for Macintosh, GraphPad Software, La Jolla California USA,
 207 www.graphpad.com) (Levenberg 1944; Marquardt 1963) converges to the values of MAP and AnS that minimize the
 208 sum of squares of the differences between Equation 8 and Equation 9 over several for various couples of the equality:

$$\begin{aligned}
 210 \quad & 25.8 d_{tot} BPT^{-1} + 0.68 d_{tot}^3 BPT^{-3} (1 - d_{acc}/d_{tot} + 0.5 d_{acc}/d_{tot}) + 193.2 d_{tot}^2 BPT^{-3} = \\
 211 \quad & = AnS BPT^{-1} + [MAP - MAP \tau (1 - e^{-BPT\tau^{-1}})t_e^{-1}] \quad (11,
 \end{aligned}$$

212
 213 where MAP and AnS are unknown.

214 In the present study, \dot{E}_c over 200 m, 500 m, 750 m, 1000 m and 3000 m in the 2012 and 2013 Men Master World
 215 Championships together with the world records over the same distances were calculated for the following decades: 35 –
 216 39 yy; 40 – 44 yy, 45 – 49 yy, 50 – 54 yy, 55 – 59 yy, 60 – 64 yy, 65 – 69 yy, 70-74 yy and 75 - 80 yy. Track cycling
 217 performances were obtained from the UCI Track Cycling masters World Championships web page
 218 (<http://www.cyclingmasters.com> accessed on May 2014). Best performances of the 200 m race were included even
 219 though it is a flying start competition disregarding the fact that the athletes were not starting from a stationary start. For
 220 the calculations, the performances in the World Championships of the three first standings were always considered. In
 221 the youngest group of subjects, the performances over the 200 m in the 2013 World Championships were not
 222 considered for the calculations, since they were remarkably slower than the corresponding ones of the immediately
 223 older cyclists.

224 \dot{E}_c was calculated by assuming for k' , C_{rr} , C_x and η_c the values reported in the paragraphs above. M_t and A were
 225 assumed to be 85 kg and 0.43 m², respectively. ρ was calculated by assuming an air temperature of 20 °C and the
 226 average, standard barometric pressure (P_B) prevailing at the venue of the competition calculated by using a standard
 227 formula that corrects P_B as a function of altitude above sea level (Haldane and Priestley 1935).

228 For each performance time, $MAP - AnS$ values were calculated by using a value of τ in Equation 9 of 10 s, as
 229 proposed by di Prampero and colleagues (di Prampero et al. 1993). Finally, it was not corrected for age because in
 230 cycling master athletes it was found not to increase with aging from the value close to 25 s found in the youngest
 231 subjects (Berger et al. 2006).

232 95 % Confidence Intervals of the estimated MAP and AnS were always calculated from the asymptotic standard
 233 errors (Motulsky and Christopoulos 2004). The goodness of fit was quantified by using the coefficient of determination
 234 r^2 (Motulsky and Christopoulos 2004).

235 The threshold age after which *MAP* and *AnS* begin to decrease monotonically (age_0) has been identified fitting the
236 absolute values of the two parameters as a function of the age (years) by means of a two-segment linear regression.

237 To this aim, a double linear regression that minimized the squared sum of the residuals was then fitted to the *MAP*
238 and *AnS* data (GraphPad Prism version 6.00 for Macintosh, GraphPad Software, La Jolla California USA,
239 www.graphpad.com):

240

$$241 \quad f = \text{if } [x > \text{TD}, g(x), h(x)] \quad (12,$$

$$242 \quad g(x) = i_1 + (s_1 x) \quad (13,$$

$$243 \quad i_2 = i_1 + (s_1 \text{TD}) \quad (14,$$

$$244 \quad h(x) = i_2 + s_2(x - \text{TD}) \quad (15,$$

245 fit f to y ,

246

247 where f is the double linear function, x is time, and y is either *MAP* or *AnS*; TD is the time coordinate corresponding
248 to the interception of the two regression lines (the so-called threshold age); i_1 and i_2 are the intercepts of the first and
249 second linear functions, respectively; and s_1 and s_2 are the slopes. i_2 was then considered to correspond to age_0 .

250

251 **Results**

252 Some master cycling events have variable distances, depending on age. For instance, single pursuit competition foresees
253 a distance of 3000 m from 35 to 49 years athletes and of 2000 m for older athletes. Sprint distance, conversely, it is
254 identical for every age, as it considers the time necessary to cover at the highest speed the last 200 m from a flying start.
255 Therefore, the analysis of the decay of v for a given event across the age spectrum considered in the present study
256 (Table 1) is not possible as athletes of increasing decades inevitably compete over different distances.

257 On the contrary, it is possible to describe in a rather elegant way the decay of \dot{E}_c (or \dot{E}_{max}) as a function of *BPT* in the
258 nine considered intervals of age. In Figure 1, for instance, the calculated values of \dot{E}_c are plotted as a function of the
259 corresponding *BPTs* for the intervals of age corresponding to the youngest, the intermediate age and the oldest athletes
260 together with the values of *MAP* and *AnS* originated by the simulation. *MAP* and *AnS* appear, at least at first glance, to
261 decrease with age. The same data, are reported also in Table 2 with the addition of the 95 % ICs of the estimated
262 parameters.

263 A more detailed representation of the decay of *MAP* and *AnS* as a function of age is reported in Figure 2. *MAP*
264 appears to remain stable until 40 - 44 years of age; thereafter, it is characterized by a steady rate of decay with age. The
265 solution of the double segmental regression reveals that *MAP* begins to decline at an $age_0 = 42.3 \text{ y} \pm 1.9$. Afterwards, it

266 appears to decrease by $0.034 \text{ kW year}^{-1} \pm 0.002$ (0.34 kW per decade ± 0.02) with a drop of $\dot{V}O_{2max}$ per year of 0.10 L
267 $\text{min}^{-1} \pm 0.01$ ($1.3 \text{ mL min}^{-1} \text{ kg}^{-1}$ per year ± 0.13 in our hypothetical subject of 75 kg of body mass). *AnS* seems to
268 decrease after $\text{age}_0 = 49.7 \text{ y} \pm 5.3$ with an absolute average rate of decay equal to $0.94 \text{ kJ year}^{-1} \pm 0.14$ ($9.4 \text{ kJ} \pm 1.40$
269 per decade), corresponding to a drop of *AnS* expressed in equivalent of O_2 of $0.60 \text{ mL O}_2 \text{ kg}^{-1} \pm 0.09$ per year.

270 To compute the percent decay per year of *MAP* and *AnS* we calculated the percent decreases of the two parameters
271 setting to 100 % the average of the values prevailing in i) the first two (35-39 and 40 – 44 yy) and; ii) in the first three
272 decades (35-39; 40 – 44 and 45 – 49) for *MAP* and *AnS*, respectively. The data were grouped considering that the decay
273 of *MAP* and *AnS* became evident after about 45 and 48 years of age.

274 In Figure 3 the percent decay of *MAP* is reported as a function of age together with the regression lines
275 complemented with the 95 % confidence bands ($F = 234.0$; $P < 0.0001$; $r = 0.99$;). The slopes of the regression lines
276 indicate that *MAP* is characterized by a percent decay of $1.62 \% \pm 0.11$ from age_0 onwards. In the same Figure, the
277 percent decreases of *AnS* is also shown together with the corresponding regression lines and their 95 % confidence
278 bands ($F = 88.2$; $P < 0.0002$; $r = 0.97$;). In this case, *AnS* would diminish with a rate of decay of $1.08 \% \pm 0.12$ every
279 year.

280 Figure 4 shows the percent contribution of aerobic ($E_{Aer} \%$, upper panel) and anaerobic ($E_{Ans} \%$, lower panel)
281 energy sources as a function of the absolute best performance times in the decades of age considered in the study. E_{Aer}
282 and E_{Ans} were calculated from the estimated values of *MAP* and *AnS* considering the corresponding performance time.
283 The two diagrams indicate that the percent contributions of the two energy yielding pathways to the energy produced
284 during the maximal effort obviously depended on the time of the trial; however, these were apparently unaffected by the
285 age.

286

287 **Discussion**

288 By applying a model utilized for predicting best performance in track cycling we tried to describe the decay of *MAP*
289 and *AnS* that occur with increasing age in cycling master athletes. This goal was achieved by estimating the values of
290 *MAP* and *AnS* that minimized the difference between: i) the metabolic power required by the subject to cover a given
291 distance (\dot{E}_c) and; ii) the maximal metabolic power output (\dot{E}_{max}) that he was able to maintain at a constant level
292 throughout the effort. The applied method is similar to that applied by other investigators to estimate the decay with age
293 of the maximal aerobic mechanical power and the amount of mechanical work performed by using anaerobic energy
294 sources in master, skyscraper runners (Minetti et al. 2008).

295 The results of the study suggest that *MAP* starts decreasing at 45 years of age in highly trained men. Thereafter, it
296 shows an average per-cent rate of decrease of about 16 % for decade. Also *AnS* seems to decay by about 11 % per
297 decade from the second part of the fifth decade.

298

299 *Maximal Aerobic Power and Age*

300 Several papers have demonstrated that *MAP* decreases with ageing in sedentary and active men as well as in well
301 trained male master athletes (Åstrand et al. 1973; Dill et al. 1967; Maharam et al. 1999; Marcel et al. 2003, Marti and
302 Howland 1990; Pollock et al. 1967; Robinson 1938, Trappe et al. 1996). It has also been suggested that *MAP* decreases,
303 on the average, by about 10 % per decade in the general population, even though values ranging from 5 to 15 % of
304 variation every 10 years have been found for men of 20 – 75 years (Maharam et al. 1999). Conversely, the rate of
305 decrease for master athletes has been suggested to be half of that of their sedentary mates (Kasch et al. 1995; Proctor
306 and Joyner 1997; Rogers et al. 1990; Trappe et al. 1996).

307 However, whether the rate of decay of *MAP* with age in Master Athletes is lower or identical to the one found in
308 active or untrained mates remains to be elucidated. For instance, when only older fit subjects were evaluated at 68 year
309 of age, the rate of decrease of *MAP* was equal to 15 % per decade, i.e. identical to that of the untrained men (Trappe et
310 al. 1996). In addition, Polloch and colleagues (Polloch et al. 1997), during their 20-year period of longitudinal
311 observation, found a loss of only 8 % the first 10 years (from 50.5 to 60.2 years, on the average) followed to an
312 additional loss of 15 % in the second decade (from 60.2 to 70.4, years, on the average), i.e. the rate of decline seemed
313 almost double at the older age despite continued vigorous endurance during the older decades.

314 Therefore, in spite of contrasting results, the rate of reduction of *MAP* seems to accelerate in the advanced decades
315 of age and this higher rate of decrease cannot be delayed or contrasted by training.

316 Our data seem to confirm this view since *MAP* seemed to be preserved up to about 45 years of age in our master
317 athletes. This is somehow in agreement with the small rate of decay found by other investigators in the same span of

318 age. After this age, however, it decreased according to a per cent rate of decline close to the one calculated by Wiswell
319 et al. (1.2 per cent decay per year) in a group of 146 master athletes (Wiswell et al. 2001) and by Johnson and
320 colleagues (about 1.5 % decay per year) (Johnson et al. 2000). This seems to confirm that, after about the age of 50,
321 *MAP* progressively decreases despite continuous aerobic training.

322 Several physiological changes occurring with ageing may be advocated as causes of the progressive drop of *MAP*.
323 Theoretically, the progressive impairments of both maximal bulk oxygen delivery and of peripheral O₂ diffusion-
324 utilization may contribute to the observed decay of *MAP*. Maximal heart rate (HR_{max}) has been described to decrease by
325 about 1 beat per year after 10 years of age. Although a decline of HR_{max} has been shown also in master, well trained
326 athletes, its rate of decay seems to be slightly lower (a loss of about 4 to 7 beats per decade) (Kasch et al. 1995;
327 Maharam et al. 1999; Rogers et al. 1990; Pollock et al. 1997; Trappe et al. 1996) than the one observed in the general
328 population. The progressive drop of HR_{max} would imply a parallel decay of maximal oxygen delivery that would well
329 explain the concurrent drop of *MAP*. Less is known about the changes of the ventricular performances with age.
330 According to Douglas and O'Toole (Douglas and O'Toole 1992), several cardiac functions, including greater posterior
331 wall thickness, lower rapid filling velocity, higher atrial systolic velocity, and lower early-to-atrial inflow velocity
332 ratios differ in master athletes in respect to younger subjects. Master athletes are also characterized by decreased left
333 ventricular compliance compared with the young control subjects, in presence of higher cardiac pressures for a given
334 filling volume and of higher myocardial wall stress for a given strain (Arbab - Zadeh et al. 2004). However, the increase
335 of stroke volume during exercise in response to identical increase in end-diastolic volume is significantly larger in
336 master athletes than in controls. This indicates that enhanced left ventricular systolic function independent of preload
337 preserves a higher stroke volume at peak exercise and permits to attain a larger stroke volume (Seals et al. 1994). The
338 decay of *MAP* with age may be also the consequence of the progressive impairment of peripheral gas exchanges and of
339 muscular oxidative metabolism. $\dot{V}O_{2max}$ normalized per kg of appendicular muscle was found to decay in trained old
340 subjects (Proctor and Joyner 1997), so that the decline of $\dot{V}O_{2max}$ with age may be only partially explained by the
341 concomitant loss of skeletal muscle mass. However, there seems not to be conclusive evidence on the role of the
342 progressive loss of muscular oxidative metabolic capacities on *MAP*. Although we know that oxidative enzyme activity
343 (Proctor et al. 1995), capillarization (Coggan et al. 1992), mitochondrial density and oxidative capacity decay with age
344 (Conley et al. 2000; Lanza and Nair 2010), several studies have found similar muscular oxidative capacity in trained
345 young and older adults (Lanza and Nair 2010) and increased mitochondrial biogenesis and ETC activity in trained older
346 subjects (Menshikova et al. 2006). Finally, also the loss of fat-free body mass (*FFM*) may substantially contribute to the
347 age related loss of *MAP*, as regression models showed that *FFM* decline explain more the 60 % of the variation of *MAP*
348 wit age (Johnson et al. 2000).

349 *Anaerobic Capacity and Age*

350 *AnS* was shown to significantly decrease with age after the second half of the fifth decade in the present study (Figure
351 3).

352 Korhonen and colleagues (Korhonen et al. 2005) measured peak blood lactate concentration ($[La]_b$) in master male
353 runners after sprint events and showed that it declined in a curvilinear fashion with age. Marsh (Marsh et al. 1999)
354 showed that peak and mean power during a lower-limb Wingate test, as well as $[La]_b$, were significantly lower in active
355 70 years old subjects than in active, younger mates. During high-intensity, supra-maximal efforts, also the anaerobic
356 alactic fraction of total anaerobic capacity, namely the amounts of muscular *PCr* and *ATP* available to breakdown,
357 supplies a substantial amount of energy. In the present study, the estimated value of *AnS* would obviously include also
358 the alactic counterpart. It has been shown that intramuscular $[ATP]$ progressively decays with age in healthy, non-
359 athletic subjects, whereas intramuscular $[PCr]$ remains unchanged (Kerksick et al. 2015), but no data of this kind seem
360 to be available for master athletes.

361 The aforementioned drop of *AnS* observed with age may be connected both to quantitative and qualitative muscular
362 factors.

363 The loss of muscle mass with age has been broadly documented (Lexell 1993; Narici and Maffulli 2010) and it is
364 greater in the lower than in the upper limbs (Janssen et al. 2000). Although skeletal muscle mass starts declining in the
365 third decade, a remarkable decline of muscle mass is not detected until the second part of the fifth decade of age in
366 healthy elderly (Janssen et al. 2000) and a significant decline of *FFM* with age has been observed also in master
367 running athletes (Pollock et al. 1997; Trappe et al. 1996). The reduction of skeletal muscle mass volume and cross
368 sectional area is explained by the decline of fiber size (atrophy) and number (sarcopenia) (Narici and Maffulli 2010).
369 The bulk of evidence shows that Type II muscle fibers are more liable to atrophy with age (Narici and Maffulli 2010)
370 also in active, sprint male master athletes (Korhonen et al. 2006).

371 The drop in *AnS* and of performance in short-term supramaximal events observed with age could be related also to
372 qualitative muscular changes. For instance, a shift toward slower myosin isoform profiles even in sprint master athletes
373 (Korhonen et al. 2006). This may obviously contribute to the decay of performance over short distance, supra maximal
374 events. From the biochemical standpoint, increasing age is characterized by a decrease of phosphofructokinase - 1 the
375 allosterically controlled enzyme of the key reaction of glycolysis (Evans et al. 1992); this may substantially lower the
376 flux of substrate through the glycolytic pathway and the substrate - level phosphorylation rate of *ATP* synthesis.

377 Also the neuromuscular functions may undergo substantial detrimental changes with aging associated with a
378 reduction of the number and diameter of large-diameter motoneuron axons in the ventral leading to a drop of the speed
379 of conduction axonal conduction speed (Aagard et al. 2010) that becomes already evident after the fifth-sixth decade of

380 age (Mittal and Logmani 1987). It is worth noting that Grassi and colleagues attributed the deterioration of maximal
381 muscular power of the lower found up to the age of 45 years to qualitative muscular features, whereas the subsequent
382 decay was mainly explained by the loss of muscle mass (Grassi et al. 1991).

383 In conclusion, several muscular modifications occurring with age seem to justify and explain the observed decay of
384 *AnS* and explain the decay of power during supra maximal, short distance events. Finally, they seem also in agreement
385 with the suggestion that *AnS* appears to monotonically decay after approximately the end of the fifth decade, at least in
386 this category of master athletes.

387

388 *Points of weakness and strength*

389 The model used in the present study is based on the equivalence between the metabolic power necessary to cover a
390 given distance as a function of time and the corresponding total maximal power that the subject is able to provide in the
391 same interval of time. This sort of models has been successfully utilized in the past to predict best performance times in
392 running (Péronnet and Thibault 1989; di Prampero et al. 1993) and in track cycling (Capelli et al. 1998; Olds et al.
393 1993) and to evaluate the impact of environmental conditions (Minetti et al. 2002; Péronnet and Thibault 1991) and
394 physiological factors (Capelli 1999) on maximal human performances. In all the cases, this approach has proved to
395 estimate theoretical best performance times with remarkable precision both in élite and medium level, young athletes
396 (Capelli et al. 1998; Olds et al. 199; Péronnet and Thibault 1989; di Prampero et al. 1993). Therefore, it seems to be
397 based on a sound knowledge of the physiological mechanisms dictating metabolic energy production in humans and of
398 the bioenergetical aspects of human locomotion.

399 The model at stake assumed that the total amount of energy coming from anaerobic capacity was fully available
400 independently of the time of exercise. This assumption has been questioned by some authors who proposed that it
401 increases with the duration of exhausting exercise with a time constant of 23.4 s to attain a constant value only for
402 exercises lasting longer than 120 s (Medbø and Tabata 1993). Therefore, the estimated values of *AnS* may somehow
403 overestimate the real ones as no correction for the time of exercise has been introduced. Conversely, the values of *MAP*
404 may be considered to be representative of $\dot{V}O_{2max}$ as the time duration of the longer track events was shorter than 7
405 minutes, the time limit is still valid for considering F equal to 1. The model also assumes a fixed value of the time
406 constant τ of the mono-exponential increase of muscular O_2 uptake at the onset of maximal exercise equal to 10 s, as
407 proposed in the past for similar aims (di Prampero et al. 1993). τ of the Phase II of alveolar O_2 uptake – is considered as
408 a reliable proxy of the muscular $\dot{V}O_2$ kinetics and it amounts 22 - 25 s in healthy, trained humans during moderate
409 intensity exercise (Poole et al. 2008). Therefore, the assumed value of 10 s may substantially overestimate the speed of
410 adjustment of the aerobic metabolism even in well-trained athletes. We have however to consider that in the present

411 case we deal with supra-maximal or maximal exercise conditions. Shorter τ of the Phase II were found in supramaximal
412 than during moderate intensity exercise (Adami et al. 2012). A tentative explanation of this phenomenon may be as
413 follows. Although $\dot{V}O_2$ seems to project toward the metabolic requirement imposed by the external workload, this value
414 cannot be attained, since it exceeds $\dot{V}O_{2max}$. Hence, should $\dot{V}O_2$ increase following a kinetic identical to that prevailing
415 during moderate exercise, an “apparently” shorter τ would inevitably result (Adami et al. 2012). It is worth noting that
416 Minetti and colleagues (Minetti et al. 2008), who estimated the decay of *MAP*, *ANS* and τ in master skyscraper runners
417 by applying an approach similar to the one proposed in the present investigation, found values of τ ranging from 5 s to
418 9 s in athletes 45 – 65 years old.

419 We also know that τ increases with age in moderately active subjects (DeLorey et al. 2004). Conversely, it did not
420 significantly changed with aging in endurance trained master athlete (Berger et al. 2006). Therefore, the assumption of
421 an invariant τ seems to be tenable in applying our model.

422 The calculation of the metabolic power required covering a given d depends also on the total mass (Eq. 1), which
423 obviously included the subject’s body mass. Indeed, muscle mass and lean body mass have been found to decrease with
424 age even in master athletes (Fleg and Lakatta 1988; Wiswell et al. 2001). However, total body mass in master athletes
425 seems to be preserved across a broad spectrum of age (Trappe et al 1996; Wiswell et al. 2001).

426 Of course, as the calculations are crucially based on best performance times, the reliability of the data - base of these
427 values is the uppermost requirement for this sort analysis. These values might be not fully illustrative of the
428 physiological features of some categories of master athletes where world championship competitions are not yearly
429 organized and where absolute best performances may not be systematically recorded.

430 The main point of strength of study consists in the attempt of estimating with an indirect approach, not only the
431 decay of *MAP* across the age spectrum – which has been directly assessed in several cross-sectional or longitudinal
432 investigations in the past –, but also that of anaerobic capacity, i.e. of an additional physiological parameter determining
433 human performances during short-term, supra – maximal efforts. This approach, may be applied to all the types of
434 human locomotion – running (Rittweger et al. 2009), swimming (Zamparo et al. 2012), kayaking, canoeing, cross
435 country skiing, etc. etc. of whom the relationship between speed and the corresponding C is known and described in
436 terms of terrain inclination, type of surface, technical tools utilized for moving or applied techniques, etc. etc. As such,
437 it would allow us obtain an overall and broader picture of the decay of human exercise capacity, and of its energetic
438 determinants, with ageing.

439

440

441

442 *Conclusions*

443 In conclusion, by applying a theoretical model for predicating human best performances in track cycling, we estimated
444 the decay of *MAP* and *AnS* of male master athletes. These two physiological parameters are important factors
445 determining human performances (Capelli 1999) and are affected in a multifactorial fashion by ageing. The analysis
446 suggests that they initiate to drop from the fifth decade of age. Afterwards, *MAP* declines by about 16 % per decade, as
447 previously shown in other classes of master athletes. Also *AnS* shows a linear decay of about 11 % per decade, which
448 might be mainly related to the progressive loss of muscle mass in the lower limbs and to the progressive deterioration of
449 the anaerobic energy yielding pathways and neuromuscular characteristics.

450

451 **Conflict of interest**

452 The authors declare no conflict of interest. The study was funded by the FUR 2014 – UNIVR allocated to Carlo Capelli
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454

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- 583

584 **Figure Legends**

585

586 Figure 1: \dot{E}_c of master athletes as a function of performance times in the youngest, intermediate age and oldest
587 groups of subjects.

588

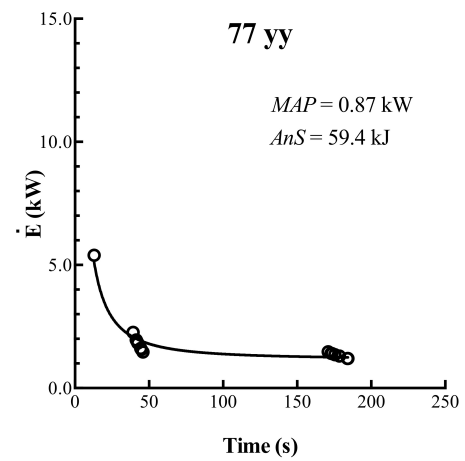
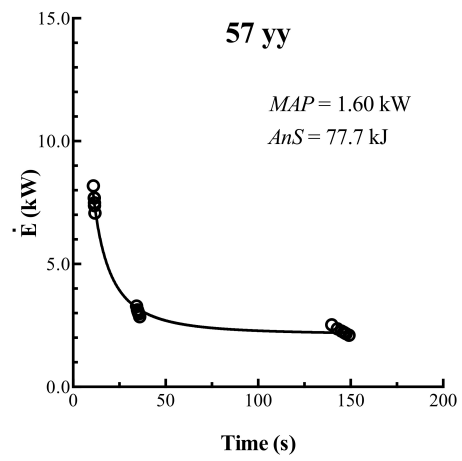
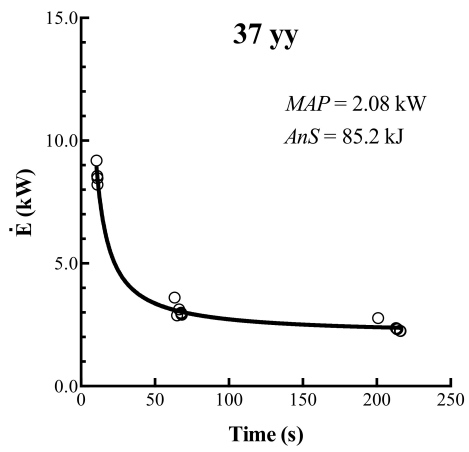
589 Figure 2: Absolute values of *MAP* (upper panel) and *AnS* (lower panel) as a function of age. The arrows indicate
590 the age (age_0) after which *MAP* and *AnS* start monotonically decreasing.

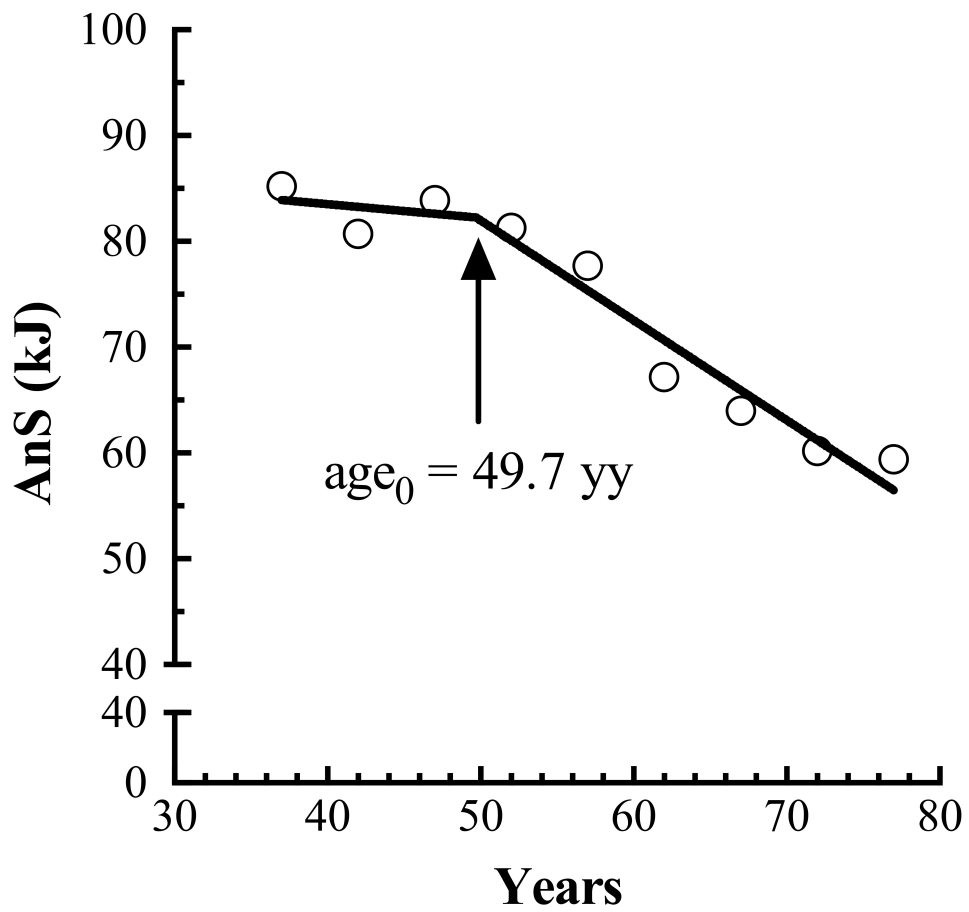
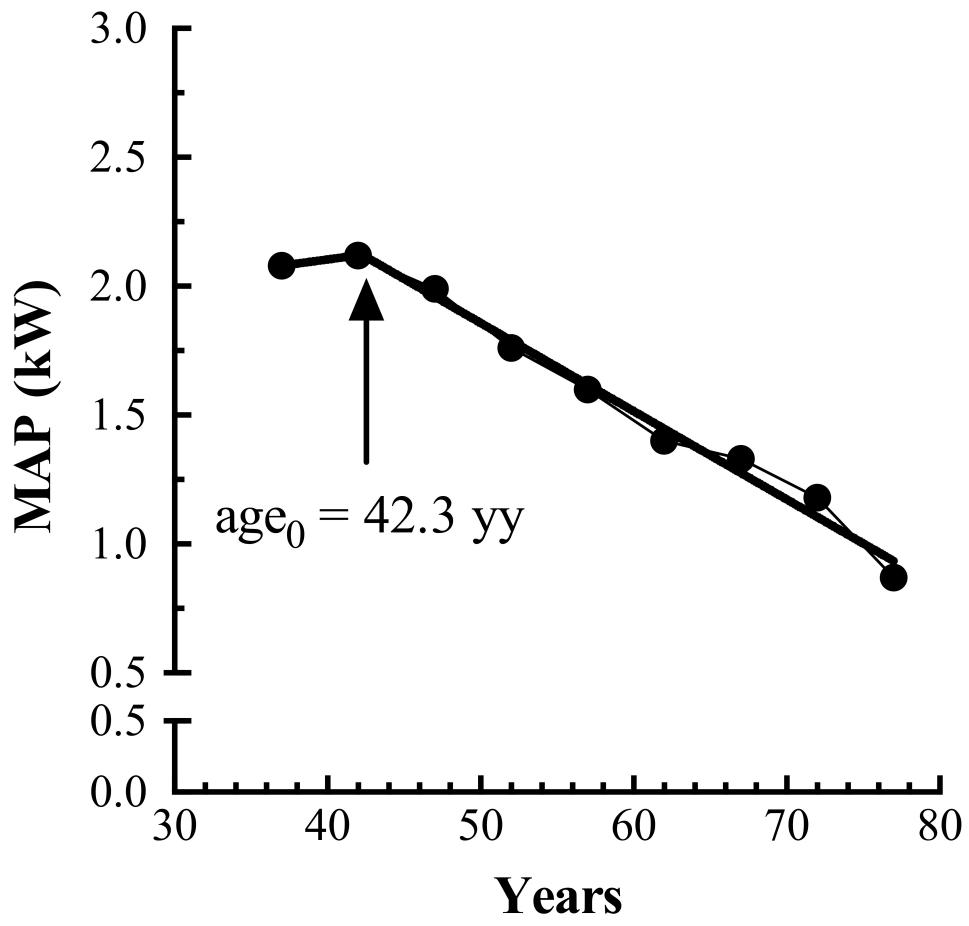
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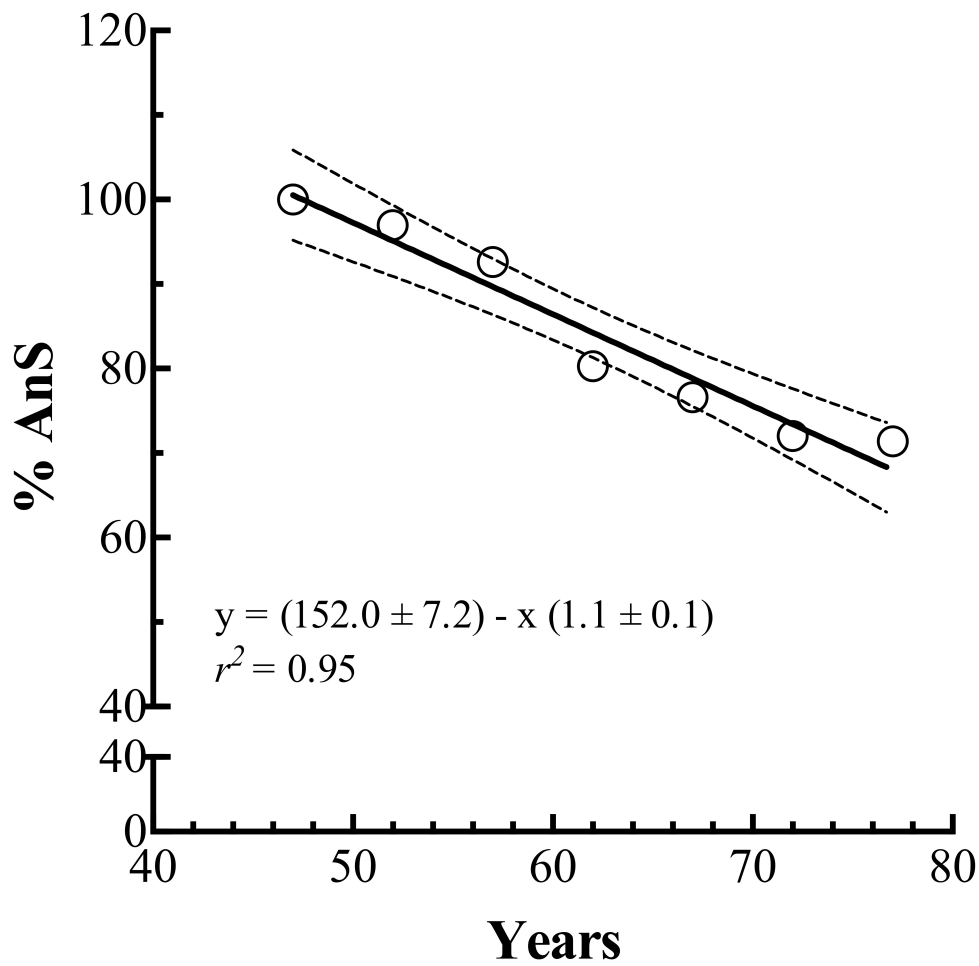
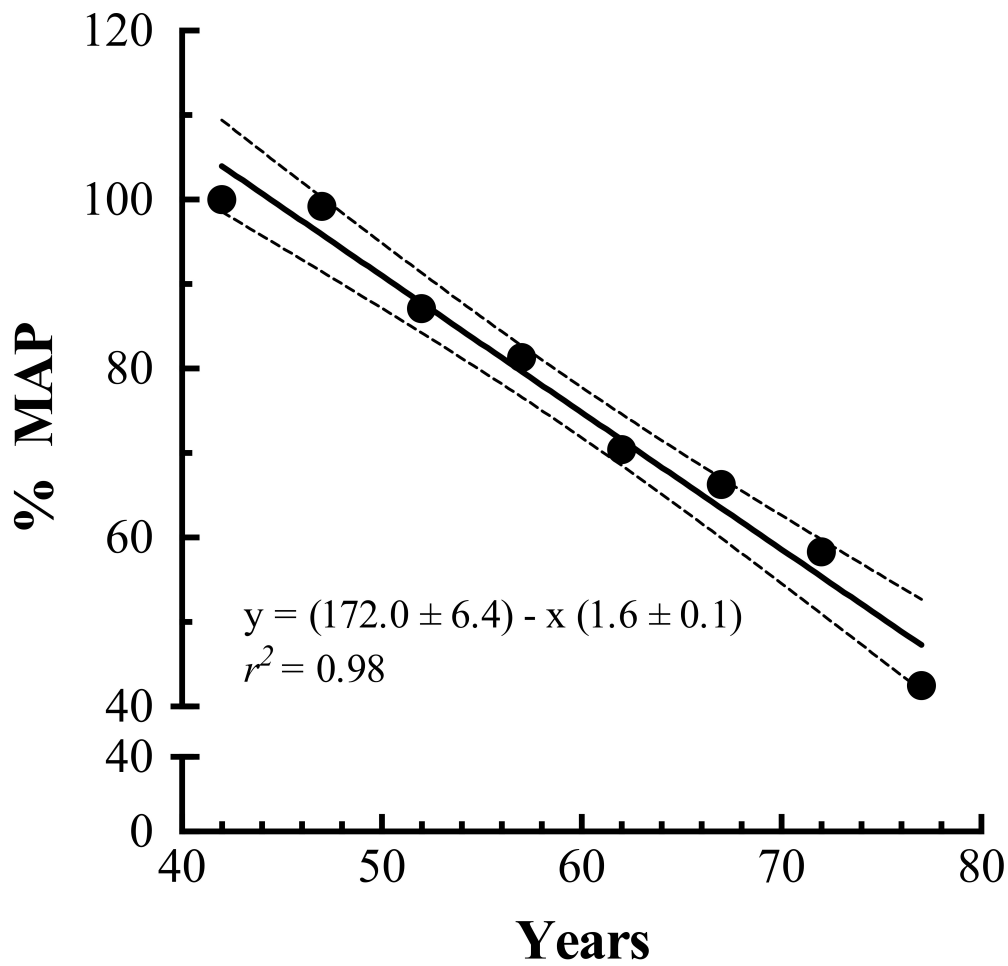
592 Figure 3: Percent decrease of *MAP* (upper panel) and *AnS* (lower panel) as a function of age after age_0 . The
593 regression lines with their 95 % confidence bands are also indicated.

594

595 Figure 4: Percent contribution of aerobic (E_{Aer} %, upper panel) and anaerobic (E_{AnS} %, lower panel) energy sources
596 as a function of the absolute best performance time in the different groups of age.







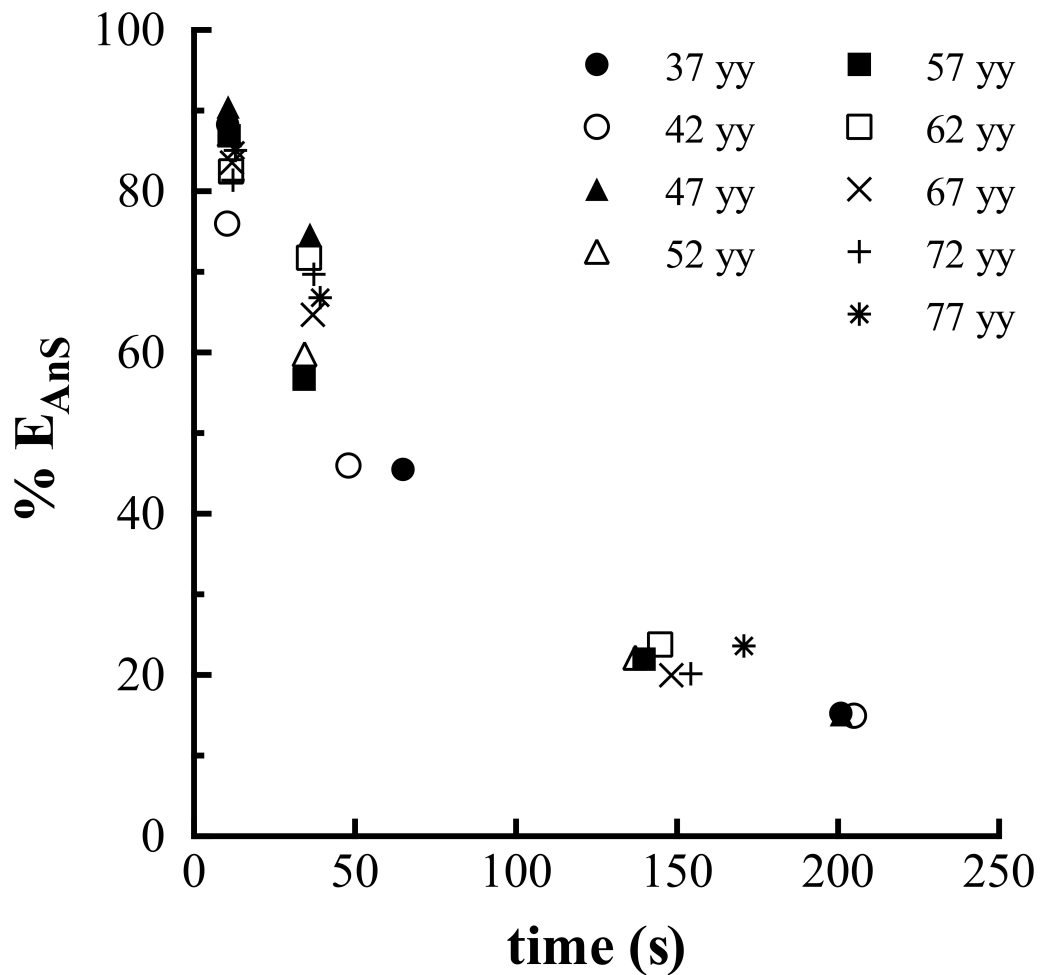
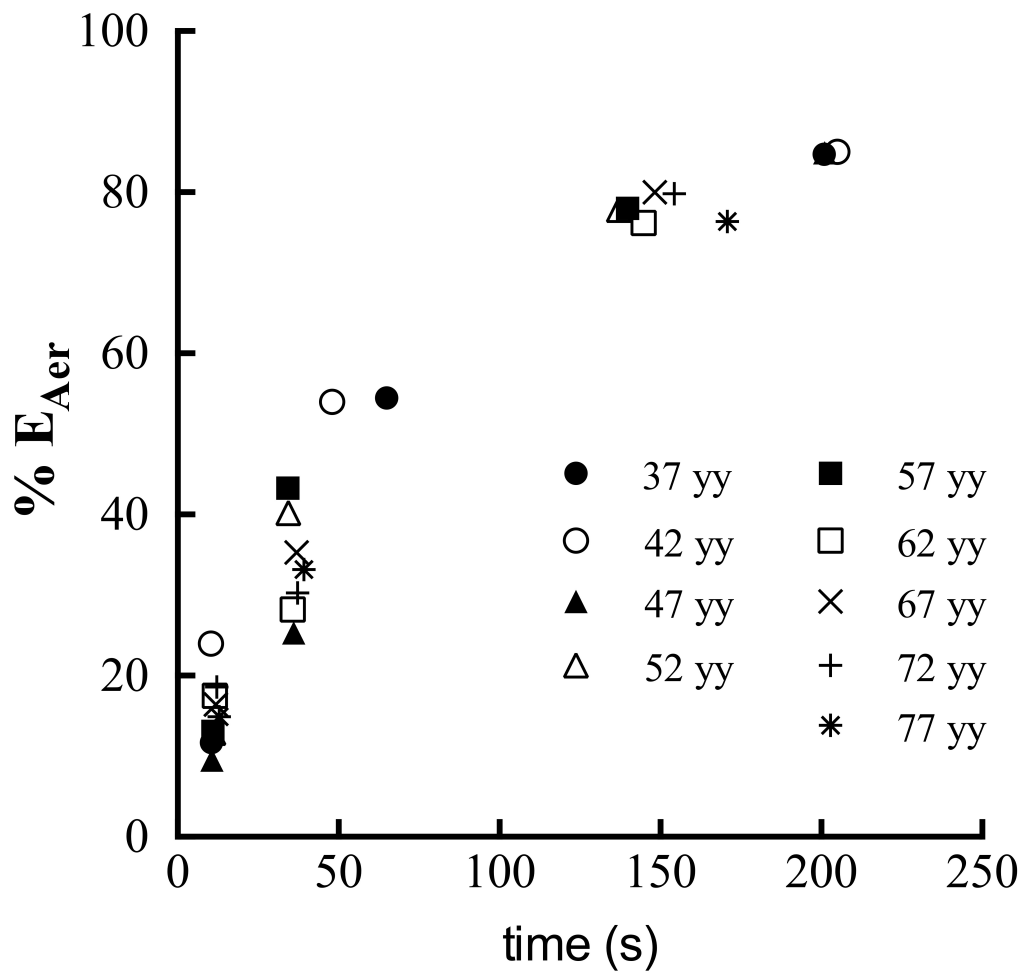


Table 1: Distance and speeds considered in the present for the calculation of *MAP* and *AnS* in the master cyclists together with the venue of the competition or record.

Age years	Distance m	Speed m s⁻¹	Event	Venue		
35 - 39	200	18.17	World Championship 2012	Manchester (GBR)		
		18.10				
		17.90				
	1000	16.16	World Championship 2013	Manchester (GBR)		
		15.19				
		15.64				
		19.60			World record	Colorado Spr. (USA)
	3000	15.07	World Championship 2012	Manchester (GBR)		
		14.74				
		14.68				
		15.81			World Championship 2013	Manchester (GBR)
		14.78				
	14.74	World record	Colorado Spr. (USA)			
	40 - 44	200	14.03	World Championship 2012	Manchester (GBR)	
			13.90			
13.89						
750		14.09	World Championship 2013	Manchester (GBR)		
		14.06				
		14.02				
		14.93			World record	Melbourne (AU)
3000		19.25	World Championship 2012	Manchester (GBR)		
		18.39				
		17.75				
		16.16			World Championship 2013	Manchester (GBR)
		15.62				
15.59		World record	Manchester (GBR)			
40 - 44		750	15.11	World Championship 2012	Manchester (GBR)	
			15.04			
	14.92					
	3000	15.33	World Championship 2013	Manchester (GBR)		
		15.11				
		14.82				
	3000	15.62	World Championship 2012	Manchester (GBR)		
		14.63				
		14.57				
14.50						
14.28		World Championship 2013			Manchester (GBR)	
14.27						
13.87	World record	Manchester (GBR)				
	14.64	World record	Manchester (GBR)			

Age years	Distance m	Speed m s ⁻¹	Event	Venue
45 - 49	200	18.30	World Championship 2012	Manchester (GBR)
		18.25		
		17.78		
		18.08	World Championship 2013	Manchester (GBR)
		17.96		
		17.84		
	18.67	World record	Colorado Spr. (USA)	
	750	15.42	World Championship 2012	Manchester (GBR)
		14.98		
		14.68		
		15.34	World Championship 2013	Manchester (GBR)
		14.80		
		14.67		
	15.42	World record	Manchester (GBR)	
	3000	14.24	World Championship 2012	Manchester (GBR)
14.23				
14.14				
14.02		World Championship 2013	Manchester (GBR)	
13.82				
13.80				
14.92	World record	Manchester (GBR)		
50 - 54	200	17.87	World Championship 2012	Manchester (GBR)
		17.62		
		17.61		
		18.01	World Championship 2013	Manchester (GBR)
		17.75		
		17.56		
	18.03	World record	Manchester (GBR)	
	500	14.32	World Championship 2012	Manchester (GBR)
		14.25		
		14.15		
		14.53	World Championship 2013	Manchester (GBR)
		14.43		
		14.21		
	14.53	World record		
	2000	14.25	World Championship 2012	Manchester (GBR)
14.24				
13.98				
14.27		World Championship 2013	Manchester (GBR)	
14.19				
13.91				
14.59	World record	Manchester (GBR)		

Age years	Distance m	Speed m s⁻¹	Event	Venue
55 - 59	200	17.50	World Championship 2012	Manchester (GBR)
		17.01		
		17.01		
		17.50	World Championship 2013	Manchester (GBR)
		17.34		
		17.25		
	18.31	World record	Colorado Spr. (USA)	
	500	14.26	World Championship 2012	Manchester (GBR)
		14.08		
		13.88		
		14.35	World Championship 2013	Manchester (GBR)
		14.18		
14.12				
14.56	World record	Manchester (GBR)		
2000	14.01	World Championship 2012	Manchester (GBR)	
	13.68			
	13.42			
	13.80	World Championship 2013	Manchester (GBR)	
	13.63			
	13.56			
14.30	World record	Manchester (GBR)		
60 - 64	200	16.50	World Championship 2012	Manchester (GBR)
		16.28		
		16.18		
		16.64	World Championship 2013	Manchester (GBR)
		16.54		
		16.03		
	17.43	World record	Colorado Spr. (USA)	
	500	13.50	World Championship 2012	Manchester (GBR)
		13.38		
		13.36		
		13.47	World Championship 2013	Manchester (GBR)
		13.43		
13.36				
14.02	World record	Colorado Spr. (USA)		
2000	13.46	World Championship 2012	Manchester (GBR)	
	13.13			
	13.11			
	13.28	World Championship 2013	Manchester (GBR)	
	13.25			
	12.85			
13.81	World record	Colorado Spr. (USA)		

Age years	Distance m	Speed m s ⁻¹	Event	Venue
65 - 69	200	16.23	World Championship 2012	Manchester (GBR)
		16.22		
		15.89	World Championship 2013	Manchester (GBR)
		16.20		
		16.01		
		15.51		
	16.87	World record	Colorado Spr. (USA)	
	500	13.34	World Championship 2012	Manchester (GBR)
		13.00		
		12.83	World Championship 2013	Manchester (GBR)
		13.35		
		13.15		
13.09				
13.53	World record	Manchester (GBR)		
2000	12.91	World Championship 2012	Manchester (GBR)	
	12.82			
	12.70	World Championship 2013	Manchester (GBR)	
	12.65			
	12.63			
	12.58			
13.48	World record	Manchester (GBR)		
70 - 74	200	15.60	World Championship 2012	Manchester (GBR)
		15.09		
		15.05	World Championship 2013	Manchester (GBR)
		15.89		
		15.64		
		15.30		
	16.56	World record	Colorado Spr. (USA)	
	500	12.96	World Championship 2012	Manchester (GBR)
		12.49		
		12.47	World Championship 2013	Manchester (GBR)
		13.05		
		12.83		
12.15				
13.39	World record	Manchester (GBR)		
2000	12.39	World Championship 2012	Manchester (GBR)	
	12.39			
	12.10	World Championship 2013	Manchester (GBR)	
	12.19			
	12.09			
	12.07			
12.95	World record	Melbourne (AUS)		

Age years	Distance m	Speed m s ⁻¹	Event	Venue
	200			
		15.46	World record	Manchester (GBR)
		11.79		
		11.14	World Championship 2012	Manchester (GBR)
		10.88		
75 - 79	500	12.10		
		12.02	World Championship 2013	Manchester (GBR)
		11.25		
		12.73	World record	Manchester (GBR)
		11.57		
		11.20	World Championship 2012	Manchester (GBR)
		10.85		
	2000	11.53		
		11.39	World Championship 2013	Manchester (GBR)
		10.87		
		11.70	World record	Manchester (GBR)

Table 2: Maximal aerobic power (*MAP*) and anaerobic capacity (*AnS*) of master athletes in the nine five-year interval of ages considered in the study. For more details, the reader is kindly asked to refer to the text.

Age years		<i>MAP</i> kW	<i>AnS</i> kJ
35 - 39	<i>95 % CI</i>	2.08 (1.94 - 2.12)	85.2 (82.8 - 87.7)
40 - 44	<i>95 % CI</i>	2.12 (1.54 - 2.69)	80.7 (72.3 - 89.1)
45 - 49	<i>95 % CI</i>	1.99 (1.816 - 2.17)	83.9 (81.36 - 86.5)
50 - 54	<i>95 % CI</i>	1.76 (1.52 - 2.00)	81.3 (77.9 - 84.7)
55 - 59	<i>95 % CI</i>	1.60 (1.39 - 1.84)	77.7 (74.7 - 80.7)
60 - 64	<i>95 % CI</i>	1.40 (1.18 - 1.62)	67.2 (64.0 - 70.4)
65 - 69	<i>95 % CI</i>	1.33 (1.13 - 1.54)	64.0 (61.0 - 67.0)
70 - 74	<i>95 % CI</i>	1.18 (0.97 - 1.39)	60.2 (56.9 - 63.4)
75 - 79	<i>95 % CI, τ_{25s}</i>	0.87 (0.61 - 1.12)	59.4 (51.2 - 67.6)