Performance declines are accelerated in the oldest-old track and field athletes 80 to 94 years of age

Original investigation

Bergita Ganse[1*], Michael Drey[2], Frank Hildebrand[3], Matthias Knobe[4], Hans Degens[1,5]

[1] Manchester Metropolitan University, Research Centre for Musculoskeletal Science & Sports Medicine, Manchester, United Kingdom

[2] Department of Medicine IV, University Hospital, LMU Munich, Munich, Germany

[3] RWTH Aachen University Hospital, Department of Orthopaedic Trauma Surgery, Aachen, Germany

[4] Department of Orthopaedic and Trauma Surgery, Lucerne Cantonal Hospital, Switzerland

[5] Institute of Sport Science and Innovations, Lithuanian Sports University, Kaunas, Lithuania

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*** address for correspondence and reprints:**

PD Dr. Bergita Ganse

Manchester Metropolitan University

Research Centre for Musculoskeletal Science & Sports Medicine

Faculty of Science and Engineering

John Dalton Building

Manchester M15GD

United Kingdom

Phone: +49 1755300960

E-mail: b.ganse@mmu.ac.uk

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ABSTRACT

Physical performance declines with age, even in exercising, healthy older individuals without major illnesses or orthopaedic issues. Declines are often reported to accelerate after the age of 70 years, but almost no data are available on performance in the fittest oldest-old. The aim of the study was to assess decline rates in performance at high age. The biggest dataset of track and field athletes ≥80 years (1567 results) ever published was collected from results lists of the years 1997 to 2019, including 100m, 200m, long jump, shot put, discus and javelin throw. Performance at age 80 of athletes still participating at age 85 was compared to those who discontinued. Only one out of every 22 athletes competing at age 80 still competed at age 90. The performance decline was more than three times as steep in athletes ≥80 (on average 1.62%/year, p-values: men: 200m $p=0.037$, all other disciplines $p<0.001$, women: shot put $p=0.017$, discus $p=0.010$) compared to athletes 30-69 years (0.46%/year), and this acceleration occurred at an average of 67 years. Performance at age 80 was similar in athletes still participating at age 85 to those who discontinued, and the variability in results was decreased after age 90. Physical performance declines more than three times as fast after around the age of 67 years compared to before. Declines are fastest in sprinting, indicating that sprinting and running exercises are most crucial for old athletes' performance. Better performing athletes did not compete longer.

INTRODUCTION

Other than many of their sedentary peers or patients with orthopaedic constraints, master athletes continue to exercise until high age[1-4]. Maintaining high levels of physical exercise throughout the life span seems to slow the multi-systemic deterioration commonly observed in inactive individuals[5]. Accelerated declines in performance after the age of 70 have been reported in many athletic disciplines[1,6-10] and are evident even in longitudinal data[11-13]. The age of peak performance is usually reported between 18 and 23 years, and performance starts to decline progressively after staying relatively constant in the third decade of life[1].

Factors that may contribute to this age-related decline are decreases in pulmonary function[14], muscle wasting and weakness[15-16] , loss of motor units[17] and reductions in cardiovascular function[18]. World records give a rough understanding of the age-related decrement in performance[8,19], but they only reflect performance of the most exceptional individuals. While the better athletes might continue to perform well into high age, motivated by their successes, lower performers could show a faster drop in performance and stop competition altogether. If so, the accelerated decline in performance in the normal population could in fact be even steeper than that reported for world records. Until now, however, this has not been systematically investigated.

Rates of performance declines seem to differ between disciplines and types of events[1,20]. In direct comparison, aging affects anaerobic power more than aerobic power[21], but many more factors seem to determine declines in athletics performance. In a previous study comparing several athletics disciplines, we observed the steepest declines in javelin throw and 400 m (women), and in pole vault and 800 m (men), while athletes seem to perform longer in the throwing disciplines than in the sprints, runs and jumps[1]. Due to low numbers of participating athletes in the oldest age groups, decline rates are mainly unknown for the oldest age groups, apart from the running disciplines[22,23].

This information would be valuable for a more specific training advice for older athletes and to better evaluate and compensate deficiencies in frailty and sarcopenia.

We used a dataset with a substantial number of longitudinal observations to 1) analyse patterns of performance declines in the oldest group of athletes and 2) assess whether older athletes that stop competing are indeed poorer performing individuals. The hypotheses were that 1) declines in performance are accelerated at high age, and 2) better athletes continue longer, leading to an under-estimation of the actual age-related rate of decline in performance in the master athlete population.

METHODS

Ethical approval was given by RWTH Aachen University Hospital IRB (reference number EK 300/17, date of approval: October 11, 2017). Informed consent was not needed, as only data from published result lists was used.

Generation of dataset

Performance data of athletes 80 years and older were extracted from the following official ranking lists of annual best results: North Rhine 2001 – 2019 (North Rhine Track and Field Association)[24], Westfalia 2001 – 2019 (Soccer- and Track and Field Association of Westfalia)[25], Rheinland 1997 – 2019 (Rheinland Track and Field Association)[26] and Bavaria 2012 – 2019 (Bavaria Track and Field Association)[27]. All result lists are publicly available online. The named areas were selected, as their results are publicly available online and date back a decent number of years. For master athletes, annual best result lists are neither published for the world, nor for Europe or complete larger countries. The selected areas within German comprise a total population of more than 35 million, making this a valuable data-set.

Statistical analysis

All statistical tests were executed with IBM® SPSS® Statistics version 25. The six disciplines with the most participants in the targeted age group were selected for analysis: 100m and 200m sprint, long jump, shot put, discus and javelin throw. Regression analysis was performed, and regression lines and equations with their corresponding p-values are shown when significant (regression coefficient, significance level 0.05). The decline in athlete numbers with age was compared to the official population numbers in Germany (German Federal Statistical Office)[28]. A two-sided t-Test was used to compare performance of athletes who had a result at both 80 and 85 years to athletes who had a result at age 80 but not at age 85. The percent annual decline was calculated for the 80+ athletes by normalizing their performance to the average performance values at age 80 years.

For presentation purposes and to calculate the age of onset of accelerate decline, the performance for all athletes was normalized to the average performance at age 30 years. Normalisation of data is further explained in the results section. The age of onset of accelerated decline was calculated from regression equations of the younger (30–69 years) and older (≥80 years) athletes, based on the percent annual decline normalized to age 30 years, using the following formula (regression equation: $Y = aX + b$):

$$\text{Age of onset of decline} = (b_{30\text{-}69} - b_{\geq 80})/(a_{\geq 80} - a_{30\text{-}69})$$

Implement weights in the throwing disciplines stay constant for athletes older than 79 years, which means that no changes in weights of javelins, discusses and shots affect absolute results. The following implements are used by athletes 80 years and older: shot put: men 3 kg, women 2 kg, discus throw: men 1 kg, women 750 g, javelin throw: men and women 400 g. In data of younger athletes, changing implement weights affect results of regression statistics.

RESULTS

Characterization of data-set

A total of 1567 results of 80- to 94-year-old athletes (1422 and 145 results from men and women, respectively) from six athletic disciplines were included in the analysis (**Table 1**). In 80+-year-old athletes, throwing disciplines were the most popular track and field events. In men, shot put was the most popular discipline, followed by discus throw and javelin throw. For the women, discus throw was the most popular discipline, followed by shot put and javelin throw.

Participation and performance

Figure 1 shows the decline in the number of ≥ 80-year-old male (**A**) and female (**B**) participants with age and compares these numbers to official population numbers for Germany in the year 2019 (**C**). While the overall pattern of population and participation decline with age appears similar, the proportion of the population participating in master athletics decreases with increasing age (**D**). Overall, there were 415 results of 80-year-old (women and men) and only 19 of 90-year-old athletes. This means that only one out of 22 athletes who competed at age 80 still participated at age 90. **Figure 2** shows individual longitudinal changes of performance in shot put (the most popular discipline) in absolute (**A**) values and as % of performance at age 80 years (**B**). It can be seen that the performance declined in the large majority of athletes.

Supplement Figure 1 shows results of regression analyses for 100m (**A**), 200m (**B**), long jump (**C**), shot put (**D**), discus (**E**) and javelin throw (**F**) in the 80+-year-old athletes. The three exceptionally slow 200m results were excluded from the analysis, as they were not representative for the master athlete population. In men, there was a linear decline in performance in all six disciplines. Exponential, logarithmic and polynomic regression models led to lower R^2 values in

all disciplines compared to linear regression. In women, due to lower participation, only the discus throw showed a significant age-related decline in performance that was similar to the rate of decline seen in men. Regression lines are only shown when significant.

The onset and rate of accelerated decline

Table 1 and **Figure 3** show the data of the present study combined with those in Ganse et al.[1]. Regression lines are shown for the 30- to 69-year-old athletes and the 80+-year-old athletes. In each discipline, the slope of performance decline is steeper in the older athletes (≥80 years) compared to those 30 to 69 years old. The regression equations were used to calculate the age of onset of an accelerated decline, defined as the age at which the two regression lines cross (**Table 1**). The average age at which the accelerated decline started was 67 years (**Table 1**). Shot put (**Figure 3B)** was the discipline with the latest onset and discus throw (**Figure 3D**) the earliest onset of accelerated decline (see also **Table1**). In **figure 3G**, we pooled the data of all disciplines and normalised the performance to the average performance at 30 years in each discipline. In **Figure 4A** it can be seen that the average performance decline after the age of 80 as a percentage of the performance at the age of 80 was 2.5%.

The end of participation is independent of performance

To answer the question whether the drop out of poorer performers affected the rate of decline, performance at age 80 of athletes who still participated at age 85 was compared to those who discontinued (**Figure 4B**). We found no difference in performance between these groups in any of the disciplines (100m: p=0.9 men; 200m: p=0.1 men; long jump: p=0.1 men; shot put: p=0.5 men and p=0.6 women; discus: p=0.9 men and p=0.9 women; javelin: p=0.9 men; due to limited numbers of athletes, women are only reported for shot put and discus throw). **Figures 4C** shows a

171 decreased variability in performance after the age of 90 years, which may reflect that at this very
172 advanced age cessation of poorer performers may play a role.
173
174 **DISCUSSION**
175
176 In the present study we analyzed 1567 competition results of 80- to 94-year-old master athletes.
177 The main findings of the study were: 1. the performance decline was on average more than three
178 times as steep in athletes ≥80 compared to athletes 30-69 years; 2. the onset of this accelerated
179 decline occurred at an average age of 66.9 years; 3. only one out of 22 athletes competing at age
180 80 still competed at age 90; 4. performance at age 80 was similar in athletes still participating at
181 age 85 to those who discontinued; 5. there was a decreased variability in results after age 90.
182
183 **Performance in athletes 80 years and older**
184 We found a faster rate of decline in performance in athletes older than 80 years than we previously
185 reported in 30- to 69-year-old athletes[1] which is in line with previous smaller studies showing an
186 accelerated decline after the age of 70[2,6-9]. One potential criticism of such studies is that they may
187 underestimate the rate of performance decline in the older master athletes as particularly the weaker
188 athletes may stop competing. In line with this criticism is our observation that the proportion of the
189 older population participating in master athletics decreases with age, suggesting that indeed frail
190 or ill individuals usually do not compete anymore. To clarify this point in more detail, we compared
191 the performance at age 80 of athletes who still participated at age 85 to those who discontinued
192 master athletics competitions and found no difference in their performance at 80 years. This thus
193 indicates that performance selection does not introduce bias in the accelerated decline we observed
194 in our 80+-year-old athletes. Further evidence supporting the decline is real, is reflected by the

195 similar coefficient of inter-individual variation in performance up to the age of 90 years and the
196 similar rate of decline in the longitudinal data on shot putters.
197 Reasons for an accelerated performance decline at very high age have not been clearly identified
198 by research. A "fading integrative physiological capacity" was suggested by Lazarus and
199 Harridge[9], and other authors indicated that a stochastic process, as seen in the accumulation of
200 DNA damage[29] is to be expected to deliver an accelerated decline in old age[30].
201
202 **The onset of an accelerated decline**
203 Our data set combined with our previous data set[1] allowed us to calculate the age at which the
204 accelerated decline occurred. Data suggest that shot put (71.6 years) was the discipline with the
205 latest, and discus throw (55.2 years) the earliest onset of accelerated decline. The early onset in
206 discus throw is certainly affected by an apparently steady performance in earlier years, caused by
207 the extensive declines in the weight of the discus with age. All disciplines require muscle power,
208 and the decrease in power with age seems to be a key factor in the decline in performance in master
209 athletes[15]. To a limited extent also changes in technique contribute, as we have shown in javelin
210 throwers[2]. Another factor might be that some disciplines are more injury-prone than others[31]. A
211 factor opposing the accelerated decline and potentially making it appear less intense than it really
212 is, is the fact that athletes on average got better over the last decades. Schneider et al.[22] showed a
213 minor effect of the calendar year on speed in sprinting and running disciplines. Kundert et al.[20]
214 showed the same for jumping and throwing events by analysing performance in the World Masters'
215 Athletic Championships 1975-2016.
216
217 **Decreased variability from age 90 years**

The similar variation in muscle mass between young adults and older people[32] suggests that the rate of muscle ageing does not differ much between individuals at population level. Similarly, we found that the variation in performance of master athletes was relatively constant up to the age of 90 years, but decreased to almost half the original variation in participants older than 90 years. The cause of this decline in variation could, in contrast to the absence of selection between 80 and 85 years, be a selection of athletes with the healthiest physiology who can continue in sports until that high age. In fact, only 1 out of 22 athletes competing at the age of 80 was still competing at the age of 90 years. These survivors deserve further study as they may reveal some factors contributing to their longevity and excellent performance into old age.

Differences between disciplines

In the present study, we found the steepest slope in percent performance decline per year in the sprint disciplines. This is a remarkable difference to the younger master athletes[1], where javelin throw and 400 m (women), and in pole vault and 800 m (men) showed the steepest declines. This finding indicates that the ability to sprint or run in particular is a very crucial limiting factor in athletic performance at high age and should be given specific priority in the attempt to counteract performance declines at high age.

Sex aspects

Ten times more men participated in track and field competitions than women, even though life expectancy of women exceeds that of men. Reasons for the lower participation of women may be related to traditional role models in the generation born in the 1930's and 1940's[33]. This influence of role model is also reflected by the relatively late introduction of organised female athletic competitions. For instance, the first women were allowed at the Olympic Summer Games in 1928

and other disciplines were opened for women much later: long jump, 200m and shot put in 1948, 400m in 1964, 5000m in 1996 and pole vault as late as 2000.

Practical applications

The present data give an indication of which performance declines to expect in the healthiest oldest-old. This is relevant in many fields, be it for the older people and athletes themselves, in rehabilitation, for decision makers, for the design of infrastructure, or for insurance companies. Most people are not aware of rates of performance decline with age, and this knowledge could help them plan their lives better and clarify expectations. On a practical level, as the decline rates are steepest in the sprints, we recommend older people to put an emphasis on trying to keep their ability to sprint or at least run, and to include sprinting in their regular exercise sessions. For the general population and/or athletes that intend to finish their sports career, it seems recommendable to include especially running and if possible, sprinting in their exercise routine.

Strengths and weaknesses

The major strength of the study is the exceptionally large amount of data of athletes older than 80 years. It is the first study to analyse such a larger number of the oldest-old athletes. A weakness is that the majority of the data are cross-sectional, but longitudinal data from a substantial number of older athletes followed the same pattern as the cross-sectional observations. In addition, we do not have data on medical history or training volumes. Due to the anonymized analysis, we are not able to name the total number of athletes included in the study, just the number of results. We also cannot provide information on the reasons for the individuals to stop competing at the end of their active competitive career, which would be desirable to have. It would also be good to see

longitudinal data of individual athletes spanning 30 years and more partnered with information on injuries and other life events to evaluate the actual aging effects on the individual participant.

CONCLUSIONS

Our study is the biggest dataset of athletes 80 years and older ever published, and it gives new insights into the rate of decline in performance and abilities of the oldest-old athletes. Performance declines accelerated around the age of 70 years and this accelerated decline is not underestimated by drop out of the poorest performers after the age of 80 years. The performance decline was more than three times as steep in athletes ≥80 compared to athletes 30-69 years. However, the lower inter-individual variability in performance after the age of 90 years might be related to the selection of the toughest in the very oldest-old.

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