Accelerated decline in javelin throwing performance in master athletes 70 years and older – does change in technique play a role?

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Background: Wile many older adults are immobile, frail and inactive, others still participate in competitive sports. As in sprinting and endurance running, the world records of javelin throwing decrease with increasing age. It is, however, not clear 1)whether this ageing-related decline is linear or, as in sprint performance, accelerates beyond the age of 69, and 2) to what extent frailty-related changes in throwing technique contribute to the decreasing performance in old javelin throwers.

Methods: We plotted the current world records against age and assessed the performance of 27 male javelin throwers 70 years and older during three master athletics championships. Three to six throws were filmed, and the best throw of each athlete selected. A step-wise linear regression was applied to assess the contribution of age, angle of release, angle of attitude , angle of attack, elbow angle just before the pull and the number of steps in the approach run, to performance.

Results: The ageing-related decline in javelin-throw performance accelerated after the age of 69 years. Age was the main predictor of performance (adjusted R^2=0.68), with a small contribution of elbow angle (adjusted R^2 increased to 0.76) and angle of attack (R^2=0.82; all P<0.001) in the older athletes. None of the technique-related parameters correlated with age.

Discussion: The ageing-related decline in javelin throwing performance was accelerated after the age of 69 years. Although the technique had some influence on javelin throwing performance, the accelerated decline in 70^+-year-old athletes was not associated with an ageing-related change in throwing technique.

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Key words: age, athletics, video, biomechanics, ageing, javelin, throwing

Introduction:

Javelin throwing was already part of the pentathlon in the first modern Olympic Games in Athens in 1896 and became a separate event in the Olympic Games in 1908. Unlike other throwing events, not only arm, upper body and core strength are required, but also speed and agility (Kunz & Kaufmann, 1983; Stanković et al., 2010). Indeed, javelin throwing consists of an approach run and the subsequent release of the javelin. The speed of the approach run (a run-up and two or three cross-over steps) appears to be one of the factors determining the success of a javelin throw. It ends in the release phase (one-legged and two-legged support phase) and finally the braking phase (Menzel, 1986), where the second-last cross-over step, the impulse step, is longer and allows the body weight to be over the rear leg to prepare for the strike. At the end of the approach run, the javelin is catapulted and in particular the velocity at release and the angle of release (the direction of pull) have been associated with good results, where the angle of release should be between 32 and 36 degrees (Kunz & Kaufmann, 1983). Further important factors are the elbow angle just before the pull and the angle of attitude (the angle between the longitudinal axis of the javelin and the horizontal line at moment of release; see Fig. 1). The difference between the angle of attitude and the angle of release is called the angle of attack (Menzel, 1986) and should be as low as possible to enhance the energy transfers to the javelin (Kunz & Kaufmann, 1983).

In recent years, master athletics, competitions for any athlete older than 35 years, has gained growing popularity, including participation in international javelin throwing competitions. In many other events, like sprinting, there is an accelerated decline in performance after the age of 70 (Berthelot et al., 2012; Korhonen, Haverinen & Degens, 2015; Cheng et al., 2016) that is at least partly attributable to an ageing-related reduction in pulmonary function (Degens et al., 2013a; Degens et al., 2013b), loss of muscle strength and changes in tendon properties (Korhonen et al., 2006; Arampatzis et al., 2011) and loss of motor units (Piasecki et al., 2016; Drey et al.,

2016). It is not known, however, whether such an accelerated ageing-related decline in older age also occurs in the performance of javelin throwing, as the performance is not only determined by physiological factors, but also, as discussed above, technique.

While many studies have been conducted on javelin throwing techniques and biomechanics in young and well performing athletes (Kunz & Kaufmann, 1983; Bartlett & Best, 1988; Viitasalo, Mononen & Norvapalo, 2003; Maryniak, Ładyżyńska-Kozdraś & Golińska, 2009; Stanković et al., 2010), as far as we know there are no studies in older javelin throwers. Master javelin throwers may well change their technique to compensate for deficits in muscle strengths, speed and agility and to minimise pain during some movements. Ageing-related changes in throwing technique within the older master athlete population may thus cause larger decrements in performance than expected from physiological changes alone. Understanding their throwing behaviour and biomechanical differences from young athletes is not only important for training and competition purposes, but also interesting for the understanding of movement and musculoskeletal and neuronal changes during the ageing process.

The aim of the present study was to assess the ageing-related changes in javelin throwing performance using the performances of master javelin throwers in three master athletics competitions. In addition, we sought to determine to what extent throwing technique contributes to performance in 69^{+}-year-old male master javelin throwers and whether the technique shows ageing-related changes in this population of athletes. It was hypothesized that javelin performance shows an accelerated decline after the age of 70 years that is at least partly attributable to ageing-related changes within this population.

Materials and Methods

Ethical approval was obtained from the RWTH Aachen University Hospital IRB (reference number EK 178/17, date of approval: August 3, 2017). Informed consent was not needed. The data were collected during three master javelin throwing competitions and anonymised before analysis, according to the declaration of Helsinki. To maintain anonymity of athletes, details on the place and date of competitions are not reported.

Age groups

In master athletics, the participants are allocated to 5-year age groups. For example, all male athletes between 80 and 84 years of age are in age group M80 and a 78-years-old male athlete is allocated to age group M75. Female athletes between the age of 85 and 89 years are in age group F85. The weight of the javelin decreases with age. While athletes 70-79 years of age use a 500 g javelin, athletes 80 years and older throw a 400 g javelin. The javelin for men up to 49 years weighs 800 g and its weight drops each decade. For the first part of the study, we retrieved the current world records for men in each age group (Wikipedia, 2017) and recorded the performance of all male javelin throwers that participated in the three competitions. The age-graded performance (AGP) was reported as a percentage of the world record at the corresponding age. We also calculated the predicted performance for each of these 27 athletes, using the regression equation of performance vs. age in the study population of 27 male 69^{+}-year-old javelin throwers. Five of these athletes participated in the age class M70, eight in M75, eleven in M80 and three in M85.

Inclusion and exclusion criteria

The inclusion criterion was participation in the javelin throw competition in age class M70 or older. To participate in the competitions, athletes did not have to qualify through previous results, but they had to be registered with a track and field club. Three to six throws of 27 male 69^{+}-year-old javelin throwers were filmed for later video analysis as described below. The best attempt of each athlete was selected for analysis. In some cases, analysis of the video images of the best throw was impossible when people standing or walking between the athlete and camera obstructed the field of view. In those cases, the next best attempt was selected. Weather conditions were fine in each of the three competitions without rain or significant wind.

Video analysis

A Canon EOS 60D camera with a Canon EF 75-300 mm zoom lens was used for filming (full HD 1920 x 1080 px, 25 fps). The camera was positioned as illustrated in figure 2. Screenshots were made of the video files and angles were calculated using Microsoft Power Point 2016. The number of steps was counted. When an athlete walked before running, only the steps of the run were counted. When an athlete only walked, the total number of steps was counted. Figure 1 shows which angles were measured and used for statistical analysis. Effects of wind were ignored. The angle of attack was calculated as:

angle of attack = angle of attitude – angle of release.

Statistical analysis

All analysis was done with SPSS (v. 23 IBM). Linear regression was performed for javelin world records versus age, and for the actual performance or AGP in the three athletic events *vs*. age for the 35-69-year-old and 69^{+}-year old athletes, separately. A stepwise linear regression was done to assess to what extent performance (actual performance (in m), AGP, and percentage of predicted performance) was determined by age, angle of attack, angle of release, angle of attitude, elbow

123 angle and steps. These factors were only fed into the model if they correlated with performance at
124 $P < 0.05$ and the adjusted R^2 is presented. Significance was assumed at $P < 0.05$. An excel file
125 with the data table that was used for statistical analysis can be found in the figshare online data
126 repository und the following URL: https://figshare.com/articles/supplement_xlsx/5661676

Results

Figure shows that the world records of javelin throwing exhibit a linear decline ($R^2 = 0.97$; $P < 0.001$). The ageing-related decline in performance of the athletes in the three events was accelerated after the age of 69 years (Fig. 3B). The age-graded performance decreased with age after the age of 69 years (Fig. 3C) indicating that the younger athletes on average performed better than the older athletes.

The stepwise linear regression showed that age was the most important predictor of actual performance in the older athletes ($R^2 = 0.68$; $P < 0.001$), with a contribution of elbow angle (R^2 increased to 0.76) and angle of attack ($R^2 = 0.82$). In an attempt to exclude the influence of age, we repeated the analysis for the age-graded. It appeared that elbow angle was then the most important determinant ($R^2 = 0.34$; $P \leq 0.001$), with additional contributions of age ($R^2 = 0.49$) and angle of attack ($R^2 = 0.60$). As age still appeared as a factor, we repeated the analysis with the predicted performance derived from the regression equation of performance *vs.* age in the older athletes. In that case elbow angle was the most important determinant of performance ($R^2 = 0.212$; $P = 0.009$) with a contribution of angle of attack ($R^2 = 0.341$).

Neither the number of steps, nor the angles of attitude, release and attack, and elbow angle showed a significant correlation with age (Figure 4).

Discussion

In the present study, 27 master athletes, age 70 years and older, were filmed during javelin throw championships and their throwing technique was analyzed. In addition, results were analyzed with regards to age-graded performance. The main observation is that in the field, the ageing-related decline in javelin-throwing performance accelerates after the age of 69 years, both in absolute terms and in terms of age-graded performance. While the performance was to some extent determined by technique, in particular by the elbow angle before the pull and the angle of attack, there was no ageing-related change in technique in the 69^{+}-year-old male javelin throwers. The accelerated decline in javelin throwing performance is most likely related to accelerated ageing-related declines in physiological function, such as muscle strength, and/or the prevention of pain during the event.

Javelin throwing performance

While the javelin-throwing world records show a linear decrease with age (Wikipedia, 2017), the ageing-related decline in the athletes that participated in the three competitions in Germany and Denmark in 2017 showed an accelerated decline after the age of 69 years. This is in line with the decline observed in sprint time and endurance events in cross-sectional (Rittweger et al., 2009; Korhonen, Haverinen & Degens, 2015) and longitudinal studies (Berthelot et al., 2012; Cheng et al., 2016). In addition, the age-graded performance of the javelin throwers decreased after the age of 69 years, but little so before that. An explanation of this phenomenon might be that the world records in the older age groups are much more influenced by individuals that have the optimal genetic constitution to perform well than that in younger age groups. Another possibility is that because of, for instance pain and/or other physical limitations many, except those very best that set the world record, use another less efficient throwing technique.

Throwing techniques in older athletes compared to those reported in younger athletes

The angle of attitude is known to be an important factor for success in javelin throw (Kunz & Kaufmann, 1983; Viitasalo, Mononen & Norvapalo, 2003; Stanković et al., 2010) and ranges in young athletes between 36° and 48°[3]. In the present study, the average release angle was below that range (32.5° on average). The same is true for the angle of release, which has been reported to be between 33° and 38° in young athletes (Menzel 1986), but on average only 29.6° in our older athlete population. This lower angle of release may be an adaptation to low muscle strength as while a high angle of release may result in a high flight path, this is only desirable when the javelin is thrown with high velocity. In older athletes who cannot release the javelin at a high enough velocity, a high angle of release will cause the javelin to land with the rear-end first, making the throw invalid and older athletes may therefore throw with a lower angle of release.

Another relevant factor might be that many older athletes already bend the elbow of the throwing arm before starting the actual throw. The average angle of the elbow just before the pull was 118.3°, while it should ideally be close to or 180°. This bending of the elbow will lead to an elevation of the javelin and a flatter release angle. It is possible that the older athletes could not keep their arms straight due to chronic damage to their shoulder and elbow joints[18], muscle weakness, lack of training in throwing techniques and/or, as discussed above for the release angle, an adaptation in throwing technique to prevent invalid throws.

The angle of attack should be as small as possible and reflects how well the impulse is transferred to the javelin (Kunz & Kaufmann, 1983; Menzel 1986). Indeed, in 12 Swiss decathletes and two world-class specialists, the better throwers had a lower angle of attack of the javelin (Kunz & Kaufmann, 1983) and elite javelin throwers still had smaller angles (Menzel 1986), even occasionally negative angles of attack (Viitasalo, Mononen & Norvapalo, 2003). The angles of

attack of the older master athletes in the present study (3.5° +/- 12.4°) were also occasionally negative and in the range of that seen in younger athletes, suggesting that the angle of attack per se does not explain the lower performance of the older than the younger javelin throwers.

The performance of javelin throwing has been reported to be positively related to the athlete's running speed (Kunz & Kaufmann, 1983; Menzel 1986; Viitasalo, Mononen & Norvapalo, 2003). In elite athletes, the length of the approach run varies between 26 and 36 meters and running speed is between 6.0 to 7.3 m/s in men (Menzel 1986). This distance was much shorter for our older athletes, and some even threw the javelin from a standing position, missing the impulse from the body to thrust the javelin forward.

The above observations do suggest that part of the lower performance in 69+-year-old than younger master javelin throwers can be attributed to a difference in technique. Further support from this comes from our observation that within the 69+-year-old male javelin thrower population the javelin throwing performance was positively related to the angle of attack and elbow angle before the pull although no such relationship was seen for angle of attitude, angle of release or number of running steps before release. The positive relationship between elbow angle and angle of attack with performance within the 69+-year-old male javelin throwers does not explain the accelerated decline in performance as there was no correlation with age for these parameters within this population. Most likely, the accelerated decline is attributable to a loss of muscle power, which in leg muscles has been shown to result in decreased 6-min walking distance and timed-up-and-go performance only if it decreased below a certain threshold level (Schmitt et al., 2001; Maden-Wilkinson et al., 2015).

Study limitation

Javelin throwing is a three-dimensional and complex movement (Best, Bartlett & Morriss, 1993) and the analysis of the present study was only performed in two dimensions. However, the camera had a high resolution with exceptional video quality and was positioned perpendicular to the direction of throw, maximising the visibility of the relative angles in the plane of interest. Another limitation is that the study only considers male athletes and no females. The study is unique in that it filmed the athletes during actual competitions and that 27 athletes of 70 years and older could be filmed.

Conclusions

In conclusion, the ageing-related decline in javelin-throwing performance accelerates after the age of 69 years. While the performance was to some extent determined by technique, in particular by the elbow angle before the pull and the angle of attack, this did not explain the accelerated ageing-related decline in 69^{+}-year-old male javelin throwers. We suggest that the accelerated decline in javelin throwing performance in advanced age is a consequence of accelerated ageing-related declines in physiological function, such as muscle strength, and/or the prevention of pain during the event. The potential impact of our findings is that the theory of a linear decline in performance at high age needs to be revised and a more rapid decline expected beyond the age of 70 years. Practical implications of the study include that 1. the theory of a linear decline in performance at high age needs to be revised and a more rapid decline expected beyond the age of 70 years, 2. in older master athletes, javelin throwing performance is determined by physiological function and to some extent by technique and 3. the recommended javelin throwing technique is independent of age.

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289 **Figure legends**

290 **Figure 1:** Angles of interest during javelin throwing: **α**: angle of release, **β**: angle of attitude, **γ**:
291 angle of attack, **δ**: elbow angle just before the pull.

292 **Figure 2:** Runway and camera position seen from above. The camera was positioned in a 90°
293 angle to the arc-line ending the runway. The sector covers a 28.96° angle, the runway is 4 m wide
294 and at least 30 m long.

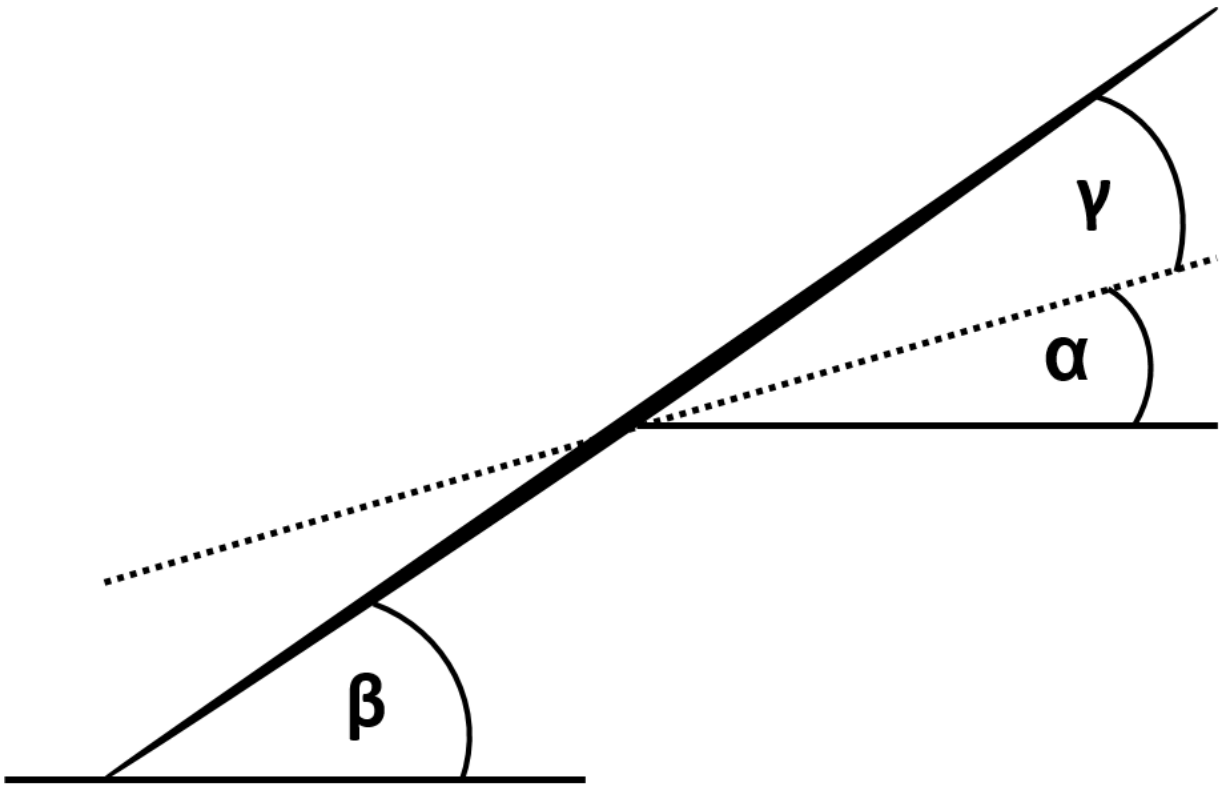
295 **Figure 3: A)** Javelin throwing world records (numbers taken from [12] on August 8th, 2017)
296 correlates negatively with age ($R^2 = 0.97$; $P < 0.001$); **B)** Javelin throwing performance in athletes
297 participating in the three competitions. The ageing-related decline is faster after the age of 69
298 years (slope younger athletes: -0.32 $m \cdot y^{-1}$; after 69 years: -1.25 $m \cdot y^{-1}$). **C)** Age-graded
299 performance in the participating athletes.

300 **Figure 4:** The elbow angle, angle of attitude, angle of attack and angle of release in male 69^{+}-
301 year-old javelin throwers.

Figure 1

Angles of interest during javelin throwing

α: angle of release, **β**: angle of attitude, **γ**: angle of attack, **δ**: elbow angle just before the pull.



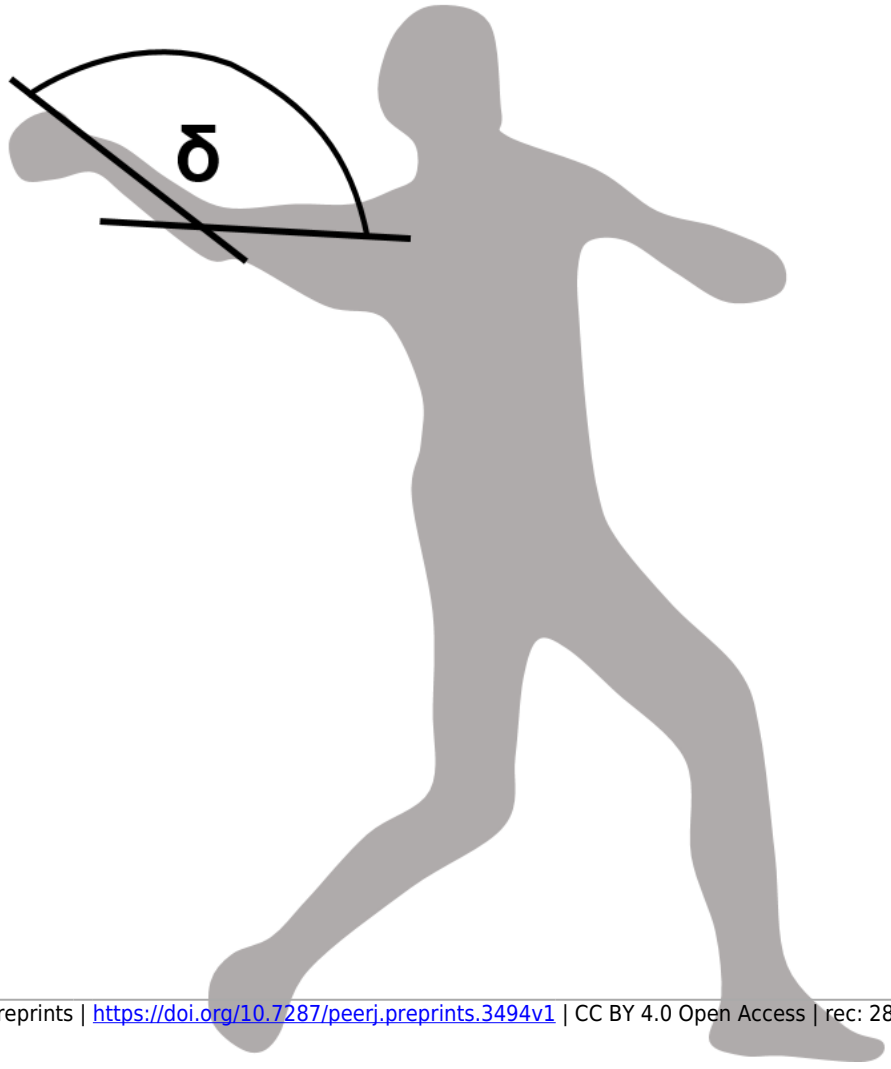


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Figure 2

Runway and camera position seen from above

The camera was positioned in a 90° angle to the arc-line ending the runway. The sector covers a 28.96° angle, the runway is 4 m wide and at least 30 m Long.

**Note: Auto Gamma Correction was used for the image. This only affects the reviewing manuscript. See original source image if needed for review.*

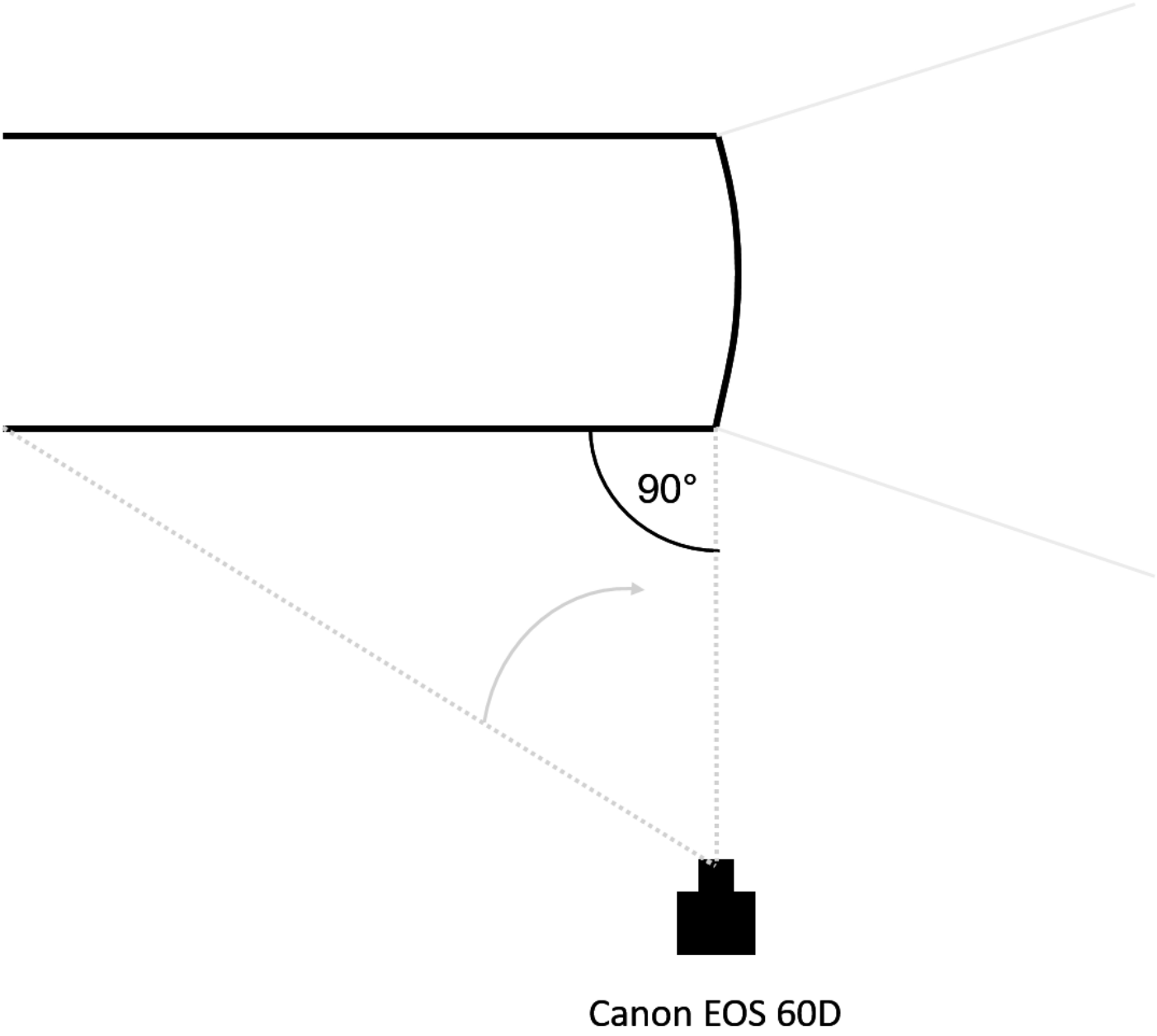
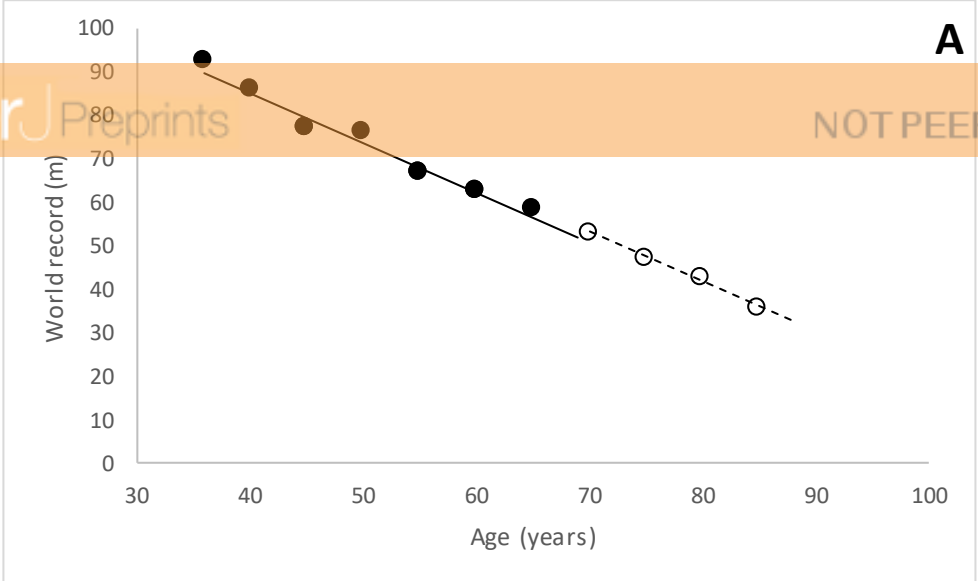
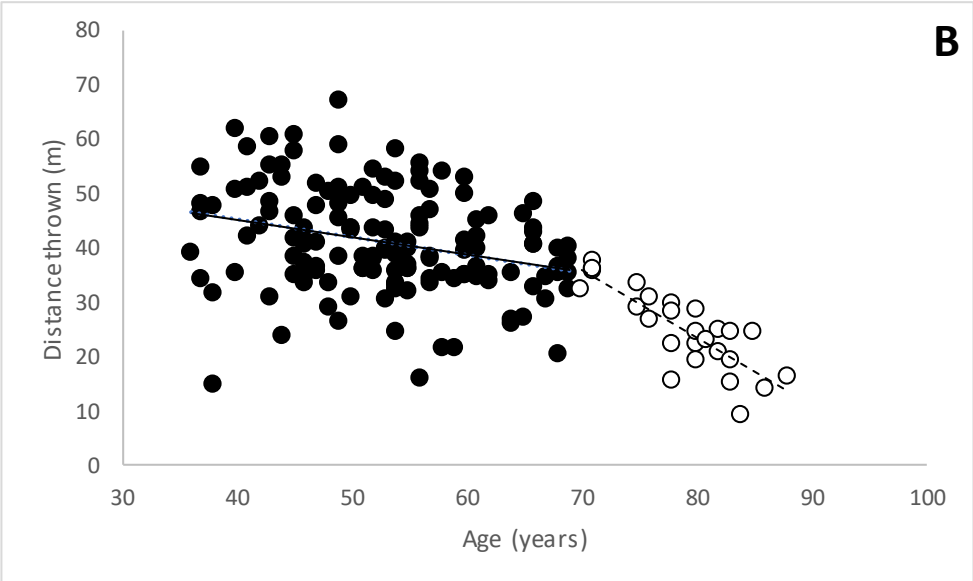


Figure 3(on next page)

World records, performance and age-graded performance

A) Javelin throwing world records (numbers taken from [12] on August 8th, 2017) correlates negatively with age (R^2 = 0.97; P < 0.001); **B)** Javelin throwing performance in athletes participating in the three competitions. The ageing-related decline is faster after the age of 69 years (slope younger athletes: -0.32 $m \cdot y^{-1}$; after 69 years: -1.25 $m \cdot y^{-1}$). **C)** Age-graded performance in the participating athletes.





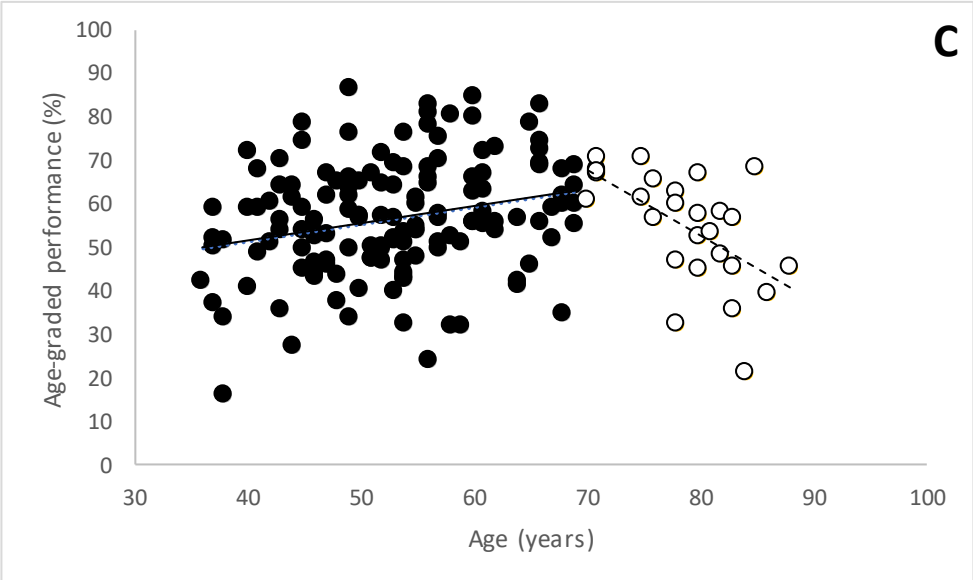


Figure 4(on next page)

Angles measured in the video analysis

The elbow angle, angle of attitude, angle of attack and angle of release in male 69^{+}-year-old javelin throwers.