THE INFLUENCE OF AGE AND REACTION TIME ON SPRINT PERFORMANCE: AN ANALYTICAL STUDY ACROSS THE LAST FIVE EDITIONS OF WORLD ATHLETICS CHAMPIONSHIPS

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ABSTRACT. *Introduction:* Sprinting performance has been shown to depend on multiple physiological variables, among which age and start reaction capacity may exert a major influence. Since hundredths of a second can decide the outcome of sprint races, understanding these factors has been considered essential. ***Objective:*** This study aimed to examine the relationships between athletes' age, reaction times at the start, and sprint performance, based on data from the last five editions of the World Athletics Championships. ***Materials and Methods:*** Official data on age, reaction times, and final results of athletes who competed in the 100 m and 200 m events (male and female) were collected and processed. Correlation statistical analyses were performed to identify potential associations between the studied variables. ***Results:*** Preliminary results showed a trend of increasing reaction times with age, as well as an association between faster reaction times and superior sprint performance. ***Discussion:*** These findings were consistent with previous studies that reported an association between increasing age and a progressive decline in reaction speed and sprint performance (Collet, 1999; Tønnessen et al., 2013; Haugen et al., 2019). Those studies showed that athletes typically reached peak sprint performance between the ages of 20 and 27, after which reaction times tended to increase, and maximal sprinting speed gradually declined. ***Conclusions:*** Age and reaction time appear to be relevant predictive factors for sprint performance and should be considered in the selection and training strategies of elite athletes.

Keywords: World championship, speed, athletics, reaction speed, age of peak

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INTRODUCTION

Sprinting widely used to benchmark neuromuscular capacities and maximal-speed technique offers a privileged setting to study performance determinants in elite competition. Among proximal outcome variables, start reaction time and athletes' age are consistently cited as key factors, acting either as direct predictors or as moderators of the strength speed to performance pathway (Valamatos et al., 2022; Harnish & Greer, 2025). Clarifying how these variables operate independently and in interaction can sharpen performance models and inform decisions on selection, periodization, and career management in high-level sprinting (Turner et al., 2025).

Peak age in sprinting generally falls in the mid-20s, with nuances by event and gender. Contemporary analyses of developmental trajectories and percentile distributions indicate that, in the 100 m, men attain optimal age slightly earlier than women, while in the 200 m and 400 m women peak a bit later (Agudo-Ortega et al., 2024). Broader reviews spanning the sprint - endurance continuum corroborate that speed - power sports peak earlier than endurance sports, with potential shifts linked to training evolution and competitive context (Harnish & Greer, 2025). These patterns align with recent syntheses on what differentiates elite performers in ≤400 m events, where biomechanical, physiological, and technical parameters are tied to success at major championships (Turner et al., 2025).

Start reaction time constrained by World Athletics' 0.100 s threshold for signaling a start before the gun remains a critical element of performance, particularly in the 100 m and 110/100 m hurdles (World Athletics, 2024). Although this threshold is a technical convention, debate persists over its validity and implementation, as micro-variations in equipment, block settings, and competition conditions can shift the distribution of recorded times (Valamatos et al., 2022). Post 2020 analyses drawing on World Championship data report robust associations between faster reactions and better final times, with gender and event specific differences (Pavlović, 2021; Zhang, 2021). Studies covering recent world level competitions, including indoors, show event-specific reaction time distributions (e.g., contrasts between 60 m and 400 m and between semifinal/final rounds) (Đukić et al., 2023/2024). Longitudinal examinations of Olympic series (2000 - 2020) likewise confirm consistent correlations especially in women's events underscoring the competitive importance of reaction time (Biswas & Bandyopadhyay, 2023). Analytical summaries for the 2022 - 2023 seasons note clustering at lower (faster) reaction values than in prior editions, plausibly reflecting athletes' adaptations and instrumentation differences, without diminishing the practical salience of start reaction in the performance equation (Valamatos et al., 2022).

The World Athletics Championships provide an ideal environment to analyze links among age, reaction time, and results due to standardized timing and sizable elite samples. The last five editions London 2017, Doha 2019, Eugene 2022, Budapest 2023, and Tokyo 2025 form a strong comparative base across continents, instrumentation setups, and micro-climates, while maintaining consistency in start rules and technical protocols (World Athletics, 2025; Olympian Database, 2025). Pragmatically, this 2017 - 2025 window also captures current cohorts' maturation, spanning rising athletes and those at or beyond peak age, enabling modeling of performance curves versus chronological age and neuromuscular reactivity indicators.

Biomechanical syntheses highlight the block push-off phase, functional asymmetries, and time to initial force factors functionally linked to measured reaction time (Valamatos et al., 2022). Complementarily, meta-analyses on post-activation performance enhancement (PAPE) suggest that targeted warm-up/conditioning can acutely modulate components relevant to the start and early acceleration, even though most evidence derives from non-competition contexts (Loturco et al., 2024). Recent predictive models for the 100 m further partition the contributions of start, acceleration, and maximal-speed phases, enabling finer estimation of how reaction time differentiates athletes amid technological and training advances (Kotuła et al., 2025).

Despite studies correlating reaction time and performance across multiple years, a gap remains: few post-2020 investigations integrate age, reaction, and final performance across the last five World Championships using a single official source (World Athletics Results) and constant technical rules. Moreover, potential age and reaction interactions (whether athletes just below or above peak age compensate via superior start reactivity) and round effects (heats, semifinals, finals) are still under quantified in comparative, inter-edition analyses (Pavlović, 2021; Đukić et al., 2023/2024).

The current research is thus justified as a comparative, multi-edition analysis with official data and replicable procedures aimed at: quantifying separate and joint effects of age and reaction on results; testing interaction terms (e.g., reaction result slopes moderated by age); mapping differences by event (100 m, 200 m, 400 m), gender, and competition phase; and generating practical recommendations for selection, planning, and race strategy (e.g., estimating how much 0.01 s in reaction "matters" by event and age). Integrating the 0.100 s rule (World Athletics, 2024) ensures interpretation within a regulated framework, reducing confusion between true reactivity differences and measurement artifacts.

Finally, the 2017 - 2025 period coincides with densification at the top of world sprinting and extended standardization of timing and block systems, alongside increased availability of official datasets (World Athletics, 2023; World Athletics, 2025). This enhances statistical robustness and external relevance for

coaches prioritizing interventions with higher expected impact (optimizing pre-start protocols for athletes near the upper bound of peak age). Building on these premises, the present study aims to: analyze the age - performance relationship in sprint events; assess the impact of start reaction time on final results; and identify age and reaction interactions within sprint performance - thereby informing age-aware preparation, adaptive training strategies, and maximization of start performance - using data from competitions of high international visibility and relevance.

The hypotheses of this research are as follows:

We assume that athletes' age has a significant relationship with sprint performance, with optimal times recorded around peak age (24 - 27 years) and a tendency for performance to decline at older ages.

We assume that start reaction time significantly influences the result, with athletes who react faster achieving better final times—especially in the 100 m and 200 m, where the start phase plays a decisive role.

We consider that there is an interaction between age and reaction time, such that the effect of reaction time on performance varies depending on the athlete's age.

MATERIALS AND METHODS

Participants

The study population consisted of athletes competing in sprint and hurdles events (100 m, 200 m, 400 m men and women; 110 m hurdles men; 100 m hurdles women; 400 m hurdles men and women) at the last five editions of the World Athletics Championships (2017 London, 2019 Doha, 2022 Eugene, 2023 Budapest, 2025 Tokyo).

Only athletes for whom complete data were available on age (years), start reaction time (s), and final time (s) were included in the analysis.

Inclusion criteria: athletes officially validated by World Athletics, with complete data for the variables listed above.

Exclusion criteria: disqualifications for false start (reaction time < 0.100 s), withdrawals, or missing data. The size of the participant pool varied by edition. In a single edition, the number of unique athletes entered across the 10 events analyzed was approximately 470 - 510, which over the five editions corresponds to a total of 2,350 - 2,550 unique athletes (central value approx. 2,450).

With regard to actual participations (across all rounds: heats, semifinals, finals), the same athlete could compete 2 - 3 times in an event; the average number per edition was 750 - 800 participations. Therefore, for all five editions combined, the estimated total is 3,750 – 4,000 actual participations (central value approx 3,875).

Procedure

Data were retrieved from publicly accessible official World Athletics databases and organized into a tabular dataset (Excel). They were then imported into specialized statistical environments for processing (IBM SPSS Statistics v.29 and R v.4.3). Prior to analysis, consistency checks were performed, and the database was cleaned by removing incomplete records.

Materials Used

Only official competition data (World Athletics Results), published after each World Athletics Championships edition, were used. Timing equipment and electronic starting-block systems were standardized by the organizers and complied with World Athletics rules, which define the start reaction threshold (0.100 s). For data processing and analysis, the following were used; Microsoft Excel 365 software for centralizing raw data; IBM SPSS Statistics v.29 and R v.4.3 software for statistical analyses; units of measurement consistent with the International System (seconds for times, years for age).

Data Analysis

The analysis was carried out on two complementary datasets:

Unique-athlete group, comprising approximately 2,350 - 2,550 athletes entered in the 10 events over the five editions (central value approx. 2,450). This dataset was used to evaluate the relationship between athletes' age and performance, since each athlete was considered only once per event.

Actual-participations group, comprising approximately 3,750 - 4,000 participations across all rounds (heats, semifinals, finals) of the five editions (central value approx. 3,875). This dataset enabled a detailed analysis of reaction times and performance by competition phase.

We ran a one-way ANOVA across age groups (<23, 23 - 27, >27), ignoring competition/year, to test whether finish time and reaction time differ by age; we report F, p, n², and descriptives, and used Tukey HSD when at least three groups were available.

We computed Pearson correlations between age and finish time, age and reaction time, and reaction time and finish time, reporting r (strength and direction), p, and N for each event and sex, with a separate sheet listing significant correlations.

RESULTS

In the women's 100 m, differences among the <23, 23 - 27, and >27 age groups are statistically significant (p = 0.00003, n^2 = 0.055): women over 27 reach the finish first, around 11.241 s, while those under 23 trail slightly at about 11.602 s. In the men's 100 m, the picture is even more clear-cut (p < 0.00001, n^2 = 0.061): the "golden" age appears to be 23 - 27 years, with 10.281 s, whereas those under 23 bring up the rear at approximately 10.552 s. In the men's 110 m hurdles, it is not the final time but the start that makes the difference: reaction times vary significantly (p = 0.00036, n^2 = 0.047), with athletes over 27 the quickest off the gun (0.145 s) and the 23 - 27 group reacting the slowest (0.156 s). In the men's 400 m, the age effect exists but is modest (p = 0.019, n^2 = 0.021): athletes over 27 record the best averages, around 45.250 s, while those under 23 remain at about 45.631 s. And in the women's 400 m hurdles, the same modest yet significant pattern repeats (p = 0.019, n^2 = 0.022): athletes over 27 dip toward 55.172 s, whereas those under 23 average around 55.869 s. Overall, age matters - especially in short sprinting and in reaction time for hurdles - but the effect is generally small to moderate, indicating that the remaining differences are driven by training, technique, and current form.

Table 1. One-way ANOVA across age groups (<23; 23 – 27; >27) for each event, analyzed separately by gender

Event	Gender	Variable (sec)	F	P	N²
100m	Women	final time	10.675	*0.000031	0.055
100m	Men	final time	13.038	*0.000003	0.061
110m hurdles	Men	reaction time	8.129	*0.000357	0.047
400m	Men	final time	4.005	*0.019032	0.021
400m hurdles	Women	final time	4.001	*0.01915	0.022

Significant differences, p< .05

Looking across all events together, when the start is slower, the final time also tends to be poorer. The relationship between reaction time and result is positive in several events—men's 100 m, men's 110 m hurdles, 200 m (mixed set), as well as women's 400 m and women's 400 m hurdles (r roughly between 0.13 and 0.19). In other words, every hundredth lost at the gun shows up, to a small extent, at the finish. Age enters the equation with an effect in the expected direction: as athletes are more mature, final times tend to be slightly better. This is evident in the women's and men's 100 m, the women's and men's 400 m, and

the women's 400 m hurdles (small negative correlations, about −0.11 to −0.29). Moreover, where the relationship is clear, age comes with a better start as well: in the men's 110 m hurdles, older athletes react slightly faster (negative correlation between age and reaction time, r ≈ −0.166).

Overall, the effects are small in magnitude but consistent and practically meaningful: a better start helps almost everywhere, and competitive maturity yields, on average, a few hundredths in favor of the final time. The remaining differences are explained by training, technique, and current form.

More concretely, in the 100 m (women and men), 400 m (women and men), and women's 400 m hurdles, age shows small negative correlations with the result (r = −0.11...-0.29), meaning more mature athletes tend to record slightly better times. In magnitude, this corresponds to roughly 1 - 8% of the variance in times explained by age.

For reaction time, the relationship with age is not consistent: it was significant only in the men's 110 m hurdles (r ≈ −0.166, 3% variance), where older athletes react slightly faster; elsewhere, the association was not significant.

Reaction time correlates positively and significantly with the final result—that is, faster reactions are associated with better finishing times—in the men's 100 m (r = 0.165, p = 0.000245, N = 491), men's 110 m hurdles (r = 0.140, p = 0.011688, N = 324), 200 m (mixed; r = 0.130, p = 0.008865, N = 404), women's 400 m (r = 0.133, p = 0.007944, N = 396), and women's 400 m hurdles (r = 0.188, p = 0.000396, N = 351), with effects that are small but consistent.

Table 2. Pearson correlations between age, reaction time, and final time,
by event and gender

Event	Gender	Variable	R	P	N
100m	Women	age_no. - result_sec.	-0.212	*0.000	371
100m	Men	reaction_sec. - result_sec.	0.165	*0.000	491
100m	Men	age_no. ↔ result_sec.	-0.207	*0.000	405
110m hurdles	Men	reaction_sec. - result_sec.	0.14	*0.011	324
110m hurdles	Men	age_no. - reaction_sec.	-0.166	*0.002	335
200m	Mixt	reaction_sec. - result_sec.	0.13	*0.008	404
400m	Women	reaction_sec. - result_sec.	0.133	*0.007	396
400m	Women	age_no. - result_sec.	-0.285	*0.00	396
400m	Men	age_no. - result_sec.	-0.153	*0.003	370
400m hurdles	Women	reaction_sec. - result_sec	0.188	*0.000	351
400m hurdles	Women	age_no. - result_sec.	-0.109	*0.041	351

Significant differences, p< .05

In the women's 100 m (result), there are two significant differences: >27 is faster than <23 by 0.361 s (p = 0.0126), and 23 - 27 is faster than >27 by 0.351 s (p = 0.0089), which orders the groups as follows: 23 - 27 (fastest) < >27 < <23.

In the men's 100 m (result), 23 - 27 outperforms <23 by 0.271 s (p = 0.0003), and >27 outperforms <23 by 0.240 s (p = 0.0046), so the order is 23 - 27 < >27 < <23.

For the men's 110 m hurdles (reaction time), >27 reacts faster than 23 - 27 by 0.012 s (p = 0.0002), and <23 is faster than 23 - 27 by 0.010 s (p = 0.0024); the resulting order of reaction times is: >27 (fastest) < <23 < 23 - 27.

Table 3. Significant Games - Howell comparisons between age groups, by event and gender

Event	Gender	Variable (sec)	Pair	Faster	P	N1	N2
100m	Women	Result	23 - 27 vs <23	23 - 27	0.008	162	79
100m	Women	Result	<23 vs >27	>27	0.012	79	130
100m	Men	Result	23–27 vs <23	23 - 27	0.000	199	109
100m	Men	Result	<23 vs >27	>27	0.004	109	97
110m hurdles	Men	Reaction time	23 - 27 vs >27	>27	0.000	175	94
110m hurdles	Men	Reaction time	<23 vs >27	>27	0.002	66	94

DISCUSSION

In summary, the post-2020 literature confirms the existence of a sprint performance peak around ages 24 - 27, with variations across events and genders (Agudo-Ortega et al., 2024; Harnish & Greer, 2025); the relevance of reaction time as a proximal determinant, with differences across events and rounds (Valamatos et al., 2022; Pavlović, 2021; Zhang, 2021; Đukić et al., 2023/2024); and the need for multi-edition analyses at the level of the World Athletics Championships to quantify interactions between age and reaction in relation to final performance (Turner et al., 2025; World Athletics, 2023). These findings motivate the present endeavor.

ANOVA results show small but consistent differences between age groups, with slightly better performances in the 23 - 27 and >27 categories. This pattern aligns with Haugen et al.'s (2018) large-sample analysis, which estimates the global sprint performance peak around ages 25 - 27, with variations by event

and gender; in hurdles, the peak tends to occur slightly later for women, which is consistent with the fact that in our data the >27 group performed well in several events (e.g., 400 m and 400 m hurdles).

Earlier, Hollings, Hopkins & Hume (2014) reached a convergent conclusion—a peak-age window roughly between 23 - 28 years, with event-specific nuances. This provides an apt framework for the observation that differences between <23 and the more mature categories appear systematically (albeit with small effects).

At an even broader scale, work led by Berthelot (multi-disciplinary time-series analyses) shows that peak age in athletics gravitates around 26 years at the species/sport level, confirming that physical and neuromechanical maturation is reflected in maximal performances. This explains why, in our correlations, age - final time is negative (older age — lower time) in several events: the effect is real but small (small percentages of variance), exactly what we would expect when looking at data aggregated across many editions.

On the "start and reaction time" front, our data show that reaction correlates positively (but weakly) with the final result in a few events (men's 100 m, men's 110 m hurdles, mixed 200 m, women's 400 m, women's 400 m hurdles): faster reaction, a slightly better outcome. The biomechanical literature adds an important nuance here. Mero's classic review (1992) emphasized that, at the elite level, reaction time alone does not strongly predict performance; the real differences stem more from the power produced in the blocks, the orientation of force, and the coordination of acceleration. This fits what a small r ($\approx$0.13 - 0.19) signifies—reaction matters, but it is not the major determinant.

Kinematic analyses. Slawinski et al. (2010) showed that elite sprinters differ from well-trained sprinters primarily in mechanical parameters of the block phase and the first steps (not in reaction per se). Likewise, Bezodis, Willwacher & Salo (2019) neatly synthesized that start performance depends on block positioning, horizontal force application, and contact times; reaction remains an important piece, but not the central one. These results explain why, in our correlations, r is positive but small: good sprinters don't win the race solely "at the gun" but through how they convert the start into efficient acceleration.

Beyond the start, for the 100 m (and, to a lesser extent, the 200/400), literature led by Morin and colleagues shows that the key determinant of performance is the force - velocity profile and the ability to orient the force vector forward during acceleration, which shortens ground contacts and increases step frequency. Our observation that a good reaction equals "a bit better at the finish", yet with a modest effect, is exactly what we would expect if the "true" performance lever is the mechanics of acceleration rather than reaction time per se.

CONCLUSIONS

This study examined relationships between age, start reaction time, and sprint performance across the last five World Athletics Championships (2017 - 2025). Using official datasets and standard procedures, we analyzed age-group differences, correlations among key variables, and event- and sex-specific patterns.

Age shows small-to-moderate but consistent associations with results. In the 100 m, the peak-age group (23 - 27) is fastest in both women and men: for women, 23 - 27 is faster than >27 by 0.351 s (p = 0.0089) and >27 is faster than <23 by 0.361 s (p = 0.0126), ordering the groups 23 – 27, >27, <23; for men, 23 - 27 outperforms <23 by 0.271 s (p = 0.0003) and >27 outperforms <23 by 0.240 s (p = 0.0046), ordering 23 – 27, >27, <23. In longer sprints, older athletes sometimes hold the advantage (e.g., men's 400 m and women's 400 m hurdles), but effect sizes remain modest. Overall, age is a meaningful predictor, with peak performance typically near 23 - 27 years and event-dependent patterns beyond that band.

Faster starts are associated with better finishes, with significant positive correlations between reaction time and final time (i.e., slower start → slower finish) in men's 100 m (r ≈ 0.165), men's 110 m hurdles (r ≈ 0.140), 200 m (mixed, r ≈ 0.130), women's 400 m (r ≈ 0.133), and women's 400 m hurdles (r ≈ 0.188). Effects are small but consistent, supporting the practical importance of reaction time while acknowledging that most variance lies in acceleration and max-speed mechanics.

Clear age differences in reaction times appear in the men's 110 m hurdles, where >27 react faster than 23 - 27 by 0.012 s (p = 0.0002), and <23 are faster than 23 - 27 by 0.010 s (p = 0.0024). However, the study did not explicitly model an age and reaction interaction (i.e., moderation of the reaction - result slope by age), so any interaction inference remains preliminary

AUTHOR CONTRIBUTIONS

Author 1, author 2, and author 3 contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

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