Breaking the athletics world record in the 100 and 400 meters: an alternative method for assessment

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Abstract: BACKGROUND The top 10 athletes in the (IAAF) in 100m and 400m ranking for each sex were assessed for their history of race times before achieving their personal record (PR). The main goal of this study was to create a new method for optimal performance improvement rate assessment for coaches and athletes aiming the World Record. METHODS The difference between PR ('actual' season) and the best race time in the last season was defined as the 1st season improvement rate (1-SIR), whereas the average improvement rate in the last and preceding seasons was the multi-season improvement rate (M-SIR). 1-SIR and M-SIR were calculated for each athlete. RESULTS The sex comparison for the 100 m event showed a significant difference in the M-SIR in favor of women. No statistical differences were identified for the 400 m event, with a trivial effect in both 1-SIR and M-SIR. CONCLUSIONS As a practical applicability, graph plots were designed to help verifying improvement rate of athletes and to evaluate whether a long-term training strategy induced an acceptable performance improvement or whether some adjustments needed and check within the plots if the improvement rate is within the average of the top-10 athletes of their event.

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ORIGINAL ARTICLE

Breaking the athletics world record in the 100 and 400 meters: an alternative method for assessment

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ABSTRACT

Background: The top 10 athletes in the (IAAF) in 100m and 400m ranking for each sex were assessed for their history of race times before achieving their personal record (PR). The main goal of this study was to create a new method for optimal performance improvement rate assessment for coaches and athletes aiming the World Record.

Methods: The difference between PR ('actual' season) and the best race time in the last season was defined as the 1st season improvement rate (1-SIR), whereas the average improvement rate in the last and preceding seasons was the multi-season improvement rate (M-SIR). 1-SIR and M-SIR were calculated for each athlete.

Results: The sex comparison for the 100 m event showed a significant difference in the M-SIR in favor of women. No statistical differences were identified for the 400 m event, with a trivial effect in both 1-SIR and M-SIR.

Conclusions: As a practical applicability, graph plots were designed to help verifying the improvement rate of athletes and to evaluate whether a long-term training strategy induced an acceptable performance improvement or whether some adjustments needed and check within the plots if the improvement rate is within the average of the top-10 athletes of their event.

Keywords: sprinting; running; performance; track-and-field

INTRODUCTION

The most popular event in the athletics is the 100 m dash, being the shortest running distance in outdoor events and characterizes the fastest man or woman in a given period and place. In contrast, in 400 m, the athlete runs a complete lap on the track, being considered by many to be the "longest sprint" and the most demanding and exhausting event in athletics (1). Due to the extreme speed, nature and popularity of these athletic events (i.e. 100m and 400m), these events could be considered as a basis for assessing the maximum capacities of human locomotion (2-4).

Mankind has been interested in a long time in assessing human performance. For instance, Tatem, Guerra (5) showed that linear models could be used to predict the progression of human performance in sprint events until the XXII century (5). On the other hand, both Blest (6) and Nevill, Whyte (7) argued that the progression of sports performance follows a nonlinear trend (6, 7). Berthelot, Sedeaud (8) in their elegant review concluded that human performance has experienced a substantial improvement in the last 20 to 30 years having as main reasons economic, social, physiological and environmental aspects, which will only be surpassed by technological evolution that will depend on the evolution of sports regulations (8).

Previous research have been conducted in an attempt to predict world records in endurance sports, such as marathons (9, 10). This research usually uses previous performance data and regression to predict future performances, and also suggests the likely characteristics of future world record holders. Studies seeking to predict performance of speed/power athletes reported that new training loads with new exercises (11, 12) and different rest time strategies (13) have been tested. However, studies on gender differences in sprint obtained little attention compared to long-

distance runners (14). Cheuvront, Carter (15) showed a smaller difference between men and women in 100 m (7.8%) when compared to greater distances such as 5 km (14%) and the marathon distance (42.195 km; 8.4%).

Additionally, methods that could predict whether the performance progression of an athlete can be judged effective enough could be of great help for athletes and coaches to vary and test new training methodologies according to the individuality of each athlete. Therefore, the present work aimed to present an alternative method to assess the progression of improvement based on the World Record in the 100 and 400m events. A comparison of these rate of improvement was also compared between men and women.

Materials and Methods

Ethical approval

All procedures used in the study were approved by the Institutional Review Board of Kanton St. Gallen, Switzerland, with a waiver of the requirement for informed consent of the participants given the fact that the study involved the analysis of publicly available data.

Sample

Data were extracted from publicly available database of the IAAF (www.iaaf.org). The first ten female and male athletes in the World Record rank of 100m and 400m events were elected to compose this sample. The athletes had recorded their, date of birth; nationality; best race time of their career (the one that got the athlete in their World Ranking position; personal record; PR); the best race

time in the season immediate before the PR; and the best race time in two or more seasons before the PR.

**** Table 1 about here ****

Procedures

Performance data from the following seasons was collected for analysis: (0) world record season; (1) season immediately before world record; (2) season two seasons before world record. The difference between the PR and the best race time in the season immediate before is the 1-season improvement rate (1-SIR), whereas the average of improvement rate in the season immediate before and seasons before that is the Multi-season improvement rate (M-SIR). These variables (1-SIR and M-SIR) were calculated individually. Further calculations in relative (%) measures were also calculated. Descriptive analysis of all data was performed and are displayed in Table 1 (100m) and Table 2 (400m).

**** Table 2 about here ****

Statistical Analysis

All data were tested for normality and homogeneity using thr Shapiro-Wilk's and Levene's tests, respectively. Variables were compared between females and males using a *t*-test for independent samples. Cohen's *d* were used to calculate effect sizes (16). Furthermore, using the descriptive data (mean, standard deviation and range) we generated a list of one thousand random entries to compose a Strauss curve for the index in each group (100m and 400m; females and males). Although the generated numbers are random, the variance and central tendencies are real, which

will serve for the purpose of this manuscript. All procedures considered an $\alpha < 0.05$. All statistical procedures were performed using Statistical Software for the Social Sciences (SPSS v.21) and Microsoft Office Excel (MS Office 2016).

RESULTS

No differences were identified between sex and age of the record athletes at 100 and 400m. The sex comparison for the 100 m event showed a significant difference in the M-SIR in favor of women, with a large effect size (Figure 1-B). No statistical differences were identified for the 400 m event, with a trivial effect in both 1-SIR and M-SIR.

**** Figure 1 about here ****

The method for optimal performance improvement rate assessment was generated through the real data of the best athletes in each category (female, male) in the 100 m and 400 m events and are displayed in Figure 2. The mean is the central value of each curve and the distance (number of standard deviations) from the mean indicates if a given athlete is improving more or less than the best athletes of the specific distance.

**** Figure 2 about here ****

DISCUSSION

147 The main objective of the study was to create an improvement rate index for
148 coaches and athletes intending to obtain a world record in 100 and 400 m in athletics.
149 We also compared the improvement rate both women and men of the 10 world record
150 holders in the 100 m and 400 m events. The gender comparison for the 100 m event
151 showed that women improved performance annually before reaching the world record
152 on average 2.6% from the previous season's record. For the 400-m, no statistical
153 difference was found.

154 Previous research that analyzed data to predict world records were mainly
155 conducted for endurance sports. For instance, non-linear regressions trying to identify
156 when the first human would be able to run a marathon before a two-hour time limit
157 (10). Other research discussed what would be the physiological and biomechanical
158 characteristics an athlete should improve to achieve the marathon goal (9). Analyzes
159 that predict sports performance are might be also very useful to identify potential
160 talents in individual sports (17). Actual performance is the main criteria to select the
161 best young athletes (18), but it should not be the only one.

162 A previous study analyzed a world record prediction in the 100 m and reported
163 that the 100 m would improve to zero seconds in the year 5038 for men 2429 for
164 women (19). Despite the impossible performance, this analysis indicates that women
165 are having a faster evolution over time. In addition, this model predicted that women
166 would be faster than men in 2060, where the finalist at the Olympic Games would
167 average 9.58s for men and 9.57s for women. The similar effect was observed for the
168 400m (19).

169 On the other hand, another study discussed whether how much more physical
170 performance improvement can be achieved before humans reach the limit (20). Some

171 authors postulate all athletic event has a limit, more specifically, the 100 m race are
172 limited to a 9-second performance for men (21).

173 In outdoor running events, the variables with the greatest influence on speed
174 production are stride length and frequency (22)in 100 m and stride length in 400 m
175 (1). These aspects may partially contribute to the differences between men and
176 women, since men generally present a higher muscle mass and strength (23, 24),
177 possibly due to the higher production of hormones involved in protein synthesis such
178 as testosterone (25, 26). However, some authors found a similar strength between
179 genders when expressed in relation to the muscle (27, 28).

180 Thus, athletes with a higher muscle mass and strength may have the ability to
181 achieve greater range with each stride and a higher frequency (24). On the other hand,
182 a study of elite athletes compared those with faster, medium and slower running speed
183 and reported that there are no differences in stride frequency, but that faster runners
184 applied a greater force against the ground, which leads to longer strides and
185 consequently faster running speeds (29).

186 Our data suggest that for a woman to reach the 100 m world record, she needs
187 to improve annually from 0.093 to 0.491 seconds. In contrast, a man usually needs to
188 improve from 0.068 to 0.226 seconds. In 400 m, women generally must improve
189 annually from 0.243 to 2.205 seconds and men from 0.253 to 1.845 seconds. For
190 athletes who fit within these limits, it is reasonable to infer that the training strategy is
191 being effective. On the other hand, for those who are improving below this range, a
192 change in training strategy should be considered. And for those who are over the top,
193 the training strategy is being very effective. In such cases, training methods may be
194 documented for further study and reproduction, and anti-doping agencies may

increase their attention to such cases. Please refer to our "Practical Applications" section for a detailed example.

CONCLUSIONS

Women improved better annually than men before reaching the 100 m world record. In addition, we provide data that can help athletes and coaches guide performance improvement in percentage and absolute values for those seeking the world record of 100 and 400 m.

PRACTICAL APPLICATIONS

The present study seeks to assist practitioners working with elite male and female athletes of the 100, 400m events. Therefore, graphs have been produced that can help to verify the improvement rate of the athletes, so that coaches can be assisted by it and know if their training methods are producing a rate of performance increase similar to World Record holders.

To apply the results from the index, an athlete should consider his best race time from present season minus his race time from the last immediate season (or the average of the last three seasons). This number is his rate of improvement and could be compared to the best ten runners within his event. Considering the plots (Figure 2), if the rate of improvement falls within:

Blue range: improves within the average of top-10 runners;
Yellow range: improves below the average of top-10, should consider a change of strategy in training;

Red range: improves very below the average of top-10, should consider a major change of strategy in training;

Green: improves above the average of top-10, training strategy are being effective and it is worth investigating the possible causes;

Dark green: improves very above the average of top-10, training strategy are being very effective and should be investigated the possible causes; doping agencies should also consider an extra care.

Example:

John races the 100m-dash with his best race time in two past seasons being 9.90sec and 10.02sec. In the present season, John performed 9.89sec.

Year	Performance (sec)	Rate of improvement (sec)
2008	10.02	-
2009	9.90	0.12
2010 (present)	9.89	0.01
Average rate of improvement		0.065

Considering the plot from Figure 2-B for males within the 100m, and average rate of 0.065sec, John falls within the yellow range. This means that a change in training strategy should be considered so that John has better gains in subsequent seasons.

Disclosure

The authors report no conflicts of interest in this work.

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302

303 **Table 1.** Descriptive data of 10 best all-time records in 100 m athletics event.

	Mean (SD)	min-max	df	t	p-value
Age (y)					
Female	26.9 (3.9)	23 – 36	17.7	0.43	0.67
Male	26.2 (3.4)	22 – 33			
Race time (s)					
Female	10.69 (0.81)	10.49 – 10.76	17.8	27.55	< 0.01
Male	9.74 (0.72)	9.58 – 9.82			
1-SIR (s)					
Female	0.181 (0.149)	0.03 – 0.47	15.3	1.11	0.28
Male	0.119 (0.095)	0.02 – 0.32			
1-SIR (%)					
Female	1.66 (1.35)	0.38 – 4.29	16.0	0.89	0.39
Male	1.20 (0.93)	0.21 – 3.16			
M-SIR (s)					
Female	0.292 (0.199)	0.07 – 0.67	11.7	2.14	0.05
Male	0.147 (0.079)	0.04 – 0.28			
M-SIR (%)					
Female	2.61 (1.73)	0.65 – 5.78	12.5	1.89	0.08
Male	1.47 (0.78)	0.36 – 2.81			

304 1-SIR: 1-season improvement rate; M-SIR: multi-season improvement rate average;

305 df: degrees of freedom.

Table 2. Descriptive data of 10 best all-time records in 400 m athletics event.

	Mean (SD)	min-max	df	t	p-value
Age (y)					
Female	24.9 (3.6)	21 – 32	17.8	0.00	1.00
Male	24.9 (3.9)	21 – 32			
Race time (s)					
Female	48.47 (0.44)	47.60 – 48.97	14.2	31.37	< 0.01
Male	43.49 (0.25)	43.03 – 43.74			
1-SIR (s)					
Female	0.838 (0.556)	0.22 – 1.82	16.1	0.75	0.47
Male	0.658 (0.488)	0.17 – 1.48			
1-SIR (%)					
Female	1.69 (1.10)	0.45 – 3.61	16.7	0.42	0.68
Male	1.48 (1.08)	0.39 – 3.29			
M-SIR (s)					
Female	1.224 (0.981)	0.48 – 3.63	15.5	0.43	0.68
Male	1.049 (0.796)	0.18 – 2.76			
M-SIR (%)					
Female	2.41 (1.83)	0.97 – 6.83	16.4	0.13	0.90
Male	2.31 (1.70)	0.41 – 5.85			

1-SIR: 1-season improvement rate; M-SIR: multi-season improvement rate average; df: degrees of freedom.

Figure 1 Boxplots and effect size of 1-SIR and M-SIR the female and male 100m and 400m. (A) sex comparison for the 100 m event 1-SIR, (B) sex comparison for the 100 m event M-SIR, (C) sex comparison for the 400 m event 1-SIR, (D) sex comparison for the 400 m event M-SIR.

Figure 2 Improvement rate index for the 100m and 400m races for men and women. (A) Improvement rate index for the 100m women, (B) Improvement rate index for the 100m men, (C) Improvement rate index for the 400m women, (D) Improvement rate index for the 400m men.