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► To cite this version:

Nicolas Forstmann, Alice Meignié, Quentin de Larochembert, Stephanie Duncombe, Karine Schaal, et al.. Does maternity during sports career jeopardize future athletic success in elite marathon runners?. *European Journal of Sport Science*, 2022, pp.1-8. 10.1080/17461391.2022.2089054 . hal-04002138

HAL Id: hal-04002138

<https://hal.science/hal-04002138v1>

Submitted on 23 Mar 2023

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To cite this article: Nicolas Forstmann, Alice Meignié, Quentin De Laroche Lambert, Stephanie Duncombe, Karine Schaal, Carole Maître, Jean-François Toussaint & Juliana Antero (2022): Does maternity during sports career jeopardize future athletic success in elite marathon runners?, European Journal of Sport Science, DOI: [10.1080/17461391.2022.2089054](https://doi.org/10.1080/17461391.2022.2089054)

To link to this article: <https://doi.org/10.1080/17461391.2022.2089054>



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Published online: 26 Jun 2022.



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Does maternity during sports career jeopardize future athletic success in elite marathon runners?

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ABSTRACT

The impact of maternity (Mat) on subsequent athletic performance is not well known. This study aims to investigate the impact of maternity among elite marathoners on their overall performance progression. For each runner listed in the top 150 female marathoners, who had experienced a mid-career maternity, performance development was reconstituted throughout the career. Maternity data and career break time span (T_{total}) were collected from publicly available informations. Performances were modelled according to the known age-performance relationship and the impact of maternity was added into the model. Linear mixed effect model was used to study the influence of maternity on the overall career. Among this sample, 37 runners had at least 1 child during her career. Among them, 14 had 2 children. Eleven runners (29.72%) made their personal best performance before Mat, which occurred at an average age of 28.40 ± 4.00 years. Twenty-six runners (70.28%) establish their best performances after Mat, at an average age of 32.20 ± 4.28 . The age-performance relationship model explains 92% of the performance variability during the career's progression. When age is considered, maternity does not have significant impact on performance development. World's most competitive marathoners can still perform at their best level after pregnancy. The ability to return and surpass previous performance level is influenced by the age at which pregnancy occurs, relative to the age of peak performance during career development.

Highlights

- Mid-career maternity does not have a significant impact on overall progression in high level runners, who return to official races.
- The ability to return and surpass previous performance level is influenced by the age at which pregnancy occurs, relative to the age of peak performance.
- Age is the variable that explains most of performance progression, independently of mid-career maternity occurrence(s).

ARTICLE HISTORY

Received 20 September 2021
Accepted 7 June 2022

KEYWORDS

female athlete; pregnancy;
performance; track/field

Introduction

Reconciling professional life and maternity leave is a challenge that many women encounter and is a predominant issue for top-level female athletes. Nowadays, it is a subject of large debate in elite women's sport. Many athletes have returned to competition after maternity leave and managed to win new titles. Nevertheless, an athlete who takes a break from competition for pregnancy may face scepticism about her possible return to high-level competition. Allyson Felix's testimony has

shown that even as a well-known champion (13 world titles and 6 Olympic titles), she faced difficulties with her sponsor when renegotiating her funding contracts. This situation was questioning her capacity to return to the highest international level (Félix, 2019). Under public spotlight, she highlighted that the choice to have a child during an elite sports career is still perceived as a risky one.

Usually, marathon runners' careers consist of initially developing speed, endurance, and experience on

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middle-distance events to later evolve towards marathon races. Using the career progression of the world's top athletics performers, as well as the world records established by age class, Berthelot et al. laid out that maximal performance ability evolves with age according to a double exponential function, progressing to a peak and then declining (Berthelot et al., 2012, 2019). Following this model and studying the age of peak performance from the 100 m to a 6-day race in 50 of the fastest runners, Marc et al. have shown that peak performance in the female marathon occurs at the age of $28.5 \text{ years} \pm 3.8 \text{ years}$ (Marc, Sedeaud, Schipman, Saulière, & Toussaint, 2018). However, beyond this peak age, many elite runners continue to establish performances that are worth of the IAAF's All-Time Top List (International Association of Athletics Federations), sometimes beyond 40 years of age. A successful running career may span most of the favourable age for procreation. Therefore, elite sportswomen may choose to temporarily interrupt competition, rather than wait until retirement.

Numerous testimonials from athletes show that a return to high level performances after pregnancy is possible. Marathon runner Paula Radcliffe won the New York City Marathon less than ten months after giving birth. Kim Clijsters won three Grand Slam titles after giving birth. The American swimmer Dara Torres won three Olympic medals after the birth of her daughter; she was 41 years old at the time (Michelson, 2018). Some even question whether pregnancy can bring psychological as well as physiological benefits (Does childbirth improve athletic ability? The Guardian, 2014). However, there is no rule of thumb for when women should resume sport after pregnancy; in addition, some athletes never recover. The International Olympic Committee published five papers that summarize common conditions, illnesses and complaints that may interfere with high level sports during and after pregnancy. They provide recommendations for training during pregnancy and after childbirth for high performance and elite athletes, and identify major gaps in the literature that limit the confidence with which these recommendations can be made (Bø et al., 2016, 2017a, 2017b, 2018). This underlines the lack of studies about several dimensions' related to postpartum recovery and especially about returning to the highest level of performance. The few available studies did not focus on the level of performance reached by elite athletes after pregnancy.

Very few investigations studied the impact of mid-career maternity among high-level athletes. A study on 34 Norwegian athletes (mean age: 33.1 years, practicing endurance, ball, aesthetic or weight-class sports) revealed that performances were similar ($n = 15$, 44%),

better ($n = 5$, 15%), lower (26%, $n = 9$) or unknown (15%, $n = 5$) in the postpartum period (3–9 months; mean: 4 months after delivery) compared with the last 6 months of the non-pregnant period (Sundgot-Borgen, Sundgot-Borgen, Myklebust, Sølvberg, & Torstveit, 2019). Their study was based on a combination of questionnaire and interview of athletes, but they did not precisely quantify performances using training data of athletes. Thus, athletes' responses might be affected by desirability bias and may therefore under or over-report training volumes. Also, data regarding training quality were not reported or detailed enough.

Research investigating the impact of maternity on athletes' performances are lacking. We therefore aimed to investigate the impact of pregnancy on performance progression among top-level marathon athletes. We hypothesized that mid-career maternity had no effect on overall performance progression among elite female marathoners.

Materials and methods

Participants and data collection

The best 150 female marathoners listed in the IAAF's All-Time Marathon Top List were identified. Information on their mid-career maternities was collected through multiple sources: the IAAF's database, as well as official national athletics websites, and in some cases, the runners' personal websites and press interviews. They were included in the study and their career was monitored, if at least one maternity was identified during the career, i.e. they established regular performances listed in the IAAF database in a given year before and after their pregnancy. Their performances and age in every official marathon event were recorded, as well as the date the events took place. In order to reconstitute the entire career development, their performances in the 1500, 3000, 5000, 10,000 m, 5 km (roadrace), 10 km and half marathons were also collected. All performance times were collected from IAAF website (www.iaaf.org). The athletes' date of birth, maternity occurrence and the career interruption duration relative to maternity were collected. Interruption time for maternity leave (T_{total}) was expressed in months and calculated as the time between the last official race participation recorded before the maternity break and the first official race following the break.

Ethics statement

This study was designed and monitored by the IRMES (Institut de Recherche bio-Médicale et d'Epidémiologie

du Sport) scientific committee. The protocol based on the use of retrospective data obtained from public sources is qualified as non-interventional. Data collection was compliant with the General Data Protection Regulation applied in European Union. A declaration of the study and database was made and approved by the "Commission Nationale de l'Informatique et des Libertés" (CNIL) in accordance with the reference methodology (MR 04) with the following registration number n° 2216328 v0.

Data analysis

Entire career development modelled according to age

In order to model the runners' performance before and after maternity, each career development was reconstituted for the 37 included athletes, from the first to the last appearance in the IAAF Top Lists, including all distances from 1500 m up to the marathon. To make the performances in these different races comparable, despite variations in distances and speeds, all performances were standardized. The standardization consisted of a performance distribution between 0 and 1, where 0 represented the worst performance sample by distance and 1 the best one, using the following formula:

$$\text{standardized value} = \frac{x - \min(X)}{\max(X) - \min(X)}$$

X : overall performance of a discipline of study sample.

Thereafter, the relationship between age and performance of our sample was modelled with the IMAP1 equation (Berthelot et al., 2019).

$$Y = a \cdot \exp\left(\left(\frac{b}{c}\right) \cdot (1 - \exp^{c \cdot t})\right) \cdot (1 - \exp^{d \cdot (t-e)})$$

Y : Standardized performance (continuous variable)

t : Age (continuous variable)

a, b, c : prevailing growth parameters

d, e : prevailing degrowth parameters

In order to strengthen the modelling of the age-performance relationship, we have set a minimum of 30 performances per age. This modelling enables to calculate: (i) the theoretical age of performance peak for the runners' cohort through the identification of the best performances at each 1-year age group and (ii) to identify the performance decline that could be explained by age only, without influence of (T_{total}). For each runner, we also identified the age at their personal best performance (PB) throughout the whole career.

Runners were then separated into two sub-groups: (1) Maternity that took place before the age at peak performance determined by IMAP1's model and (2) Maternity that took place after the age at IMAP1's peak performance. The distributions of the PB, before and after Mat, were compared for each group. Results are expressed as median (+/- Interquartile range, IQR).

Quantitative comparisons (Median Age at Mat, Age at PB, Median T_{total}) between athletes who had one or two children during their career were performed with non-parametric Wilcoxon-Mann-Whitney's tests. The level of significance was set at $\alpha = 0.05$. Results are expressed as median (\pm Interquartile range).

To evaluate the effect of (T_{total}) due to maternity leave on the runners' career progression, a linear mixed effect model was used, considering each athlete's individual variability:

$$Y_i = (\beta + \beta_i) + (\alpha_1 + \alpha_i) x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \varepsilon_{i,t}$$

x_1 : age transformed according to IMAP1
(Continuous variable)

x_2 : first maternity (boolean variable Yes / No)

x_3 : second maternity (boolean variable Yes / No)

A Fisher test was used to determine the significance of the parameters α_2 and α_3 (respectively characterizing the first and second maternity). The level of significance was set at $\alpha = 0.05$.

All statistical analyses were carried out using the dedicated statistical software, R (version 3.6.2, The R Foundation for Statistical Computing Vienna, Austria).

Results

Descriptive analysis of the cohort

Maternity age

Among the 150 top runners, 37 marathoners (24.67%) had at least one maternity leave during their career and were categorized into the maternity group (Mat) (Figure 1). Among those, 23 experienced only one mid-career maternity (group Mat1), while 14 had 2 children during their careers (group Mat2) (Figure 1). There is a mean difference of 3.6 years in the age at which these athletes had their first child between Mat1 and Mat2 (Table 1). The sample size however prevents to identify any statistical significance in that difference.

Personal best age at marathon

Eleven runners among the thirty-seven included (29.72%) had their best performance in the marathon

Selection :

- IAAF's database,
- official national athletics websites,
- runners' personal websites,
- press interviews

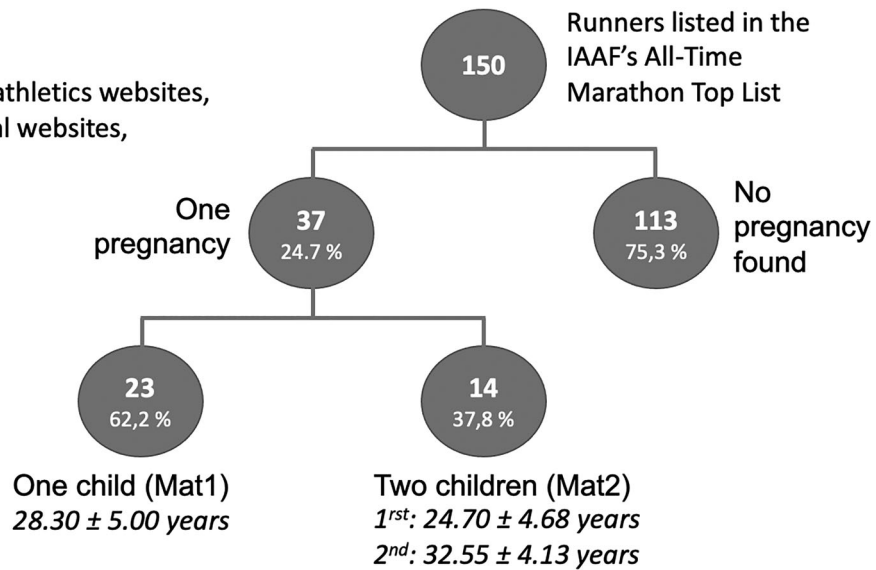


Figure 1. Flow chart of the cohort studied. Age of childbirth are indicated. Mat1: group with only one mid-career maternity. Mat2: group giving birth to two children.

before their first maternity. Twenty-six runners (70.28%) were able to establish their best performances after giving birth. The average PB in the first group is 2:21:19 ± 0:01:45 min and 2:21:03 ± 0:01:44 min in the second one.

In the Mat1 group, PB was obtained before maternity for 8 runners (34.79%) and after it for 15 (65.21%). In the

Mat2 group, PB was established for 3 (21.43%) before the first maternity, for 5 (35.71%) between births, and after the two births for 6 of them (42.86%). The length of the maternity breaks ranged from 9 months to 94 months, with a median of 23.00 (±11.00) months. Differences between T_{total} for Mat1 and Mat2 were not significant ($p = 0.689$).

Table 1. Baseline characteristics of the cohort § Considering only the first maternity. Mat 1: runners who had one maternity during their career, Mat 2: runners who had two maternities during their career. PB: personal best, T_{total} : maternity break duration.

Group	All (n = 37)	Mat1 (n = 23)	Mat2 (n = 14)	
			1st Mat	2nd Mat
Median Age (Years) at Mat (IQR)	26.20 ± 6.80	28.30 ± 5.00	24.70 ± 4.68	32.55 ± 4.13
Median Age (Years) at PB (IQR)	30.80 ± 5.40	30.80 ± 6.35	29.55 ± 4.30	
Median T_{total} (months) (IQR)	23.00 ± 11.00	22.00 ± 8.75	23.00 ± 16.50	24.50 ± 10.50
Timing of PB	Before pregnancy n = 11 (29.72%) After pregnancy n = 26 (70.28%)	Before pregnancy n = 8 (34.79%) After pregnancy n = 15 (65.21%)	Before pregnancy n = 3 (21.43%) Between 1st and the 2nd pregnancy n = 5 (35.71%) After 2nd pregnancy n = 6 (42.86%)	
Median Age at PB (IQR) before/after pregnancy	Before pregnancy: 28.40 ± 4.00 After pregnancy: 32.20 ± 4.28			

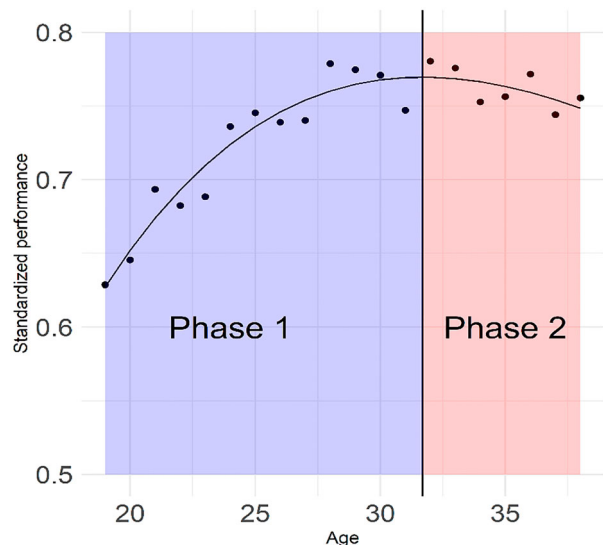


Figure 2. Relationship between age and best performance of the studied population. Each point represents the mean normalized performance (between 0 and 1) by age (from 19 to 41 years), all running events combined. The better a performance, the closer it is to 1. The period coloured in blue (Phase 1) is the period before the age at peak performance. The period coloured in red (Phase 2) is the period after the age at peak performance.

Age-performance relationship

The standardized performances of all 37 runners were modelled according to age, as shown in Figure 2 using the following equation:

$$Y = 0.89 \cdot \exp\left(\left(\frac{-5.62 \cdot 10^{-5}}{-0.29}\right) \cdot (1 - \exp^{-0.29 \cdot t})\right) \cdot (1 - \exp^{0.07 \cdot (t-2.06)})$$

Based on this model, age explains most of the variability of standardized performances ($R^2 = 0,92$). The age at peak performance, for all the different distances and events run by these athletes, was estimated at 31.7 years (IMAP1 model).

Maternity during the athletic career does not interfere with progression (before age at peak performance, Figure 3, left side) or regression dynamics (after the age of peak performance, Figure 3, right side). The analysis of standardized performances (from 1500 m to Marathon) does not reveal that pregnancy had any impact on the level of performances.

The athletes whose maternity occurred before the age of peak performance, that means, before 31.7 years, showed their best level of performance after maternity. On the contrary, those who delivered after the age of peak performance displayed their best performance before motherhood.

In the applied model, considering age and one or two maternities, we did not observe any significant influence of the first ($p = 0.874$) and second ($p = 0.349$) maternity on performance development.

Discussion

Through a performance-focused epidemiological perspective, our study examines the effects of a mid-career maternity break on the performance evolution of elite female long-distance runners. We find that a mid-career maternity does not jeopardize the career progression or the ability to perform among elite female marathoners, who return to official races.

Maternity break and age-performance progression

Our findings suggest that the age-performance relationship is not altered by maternity break: a progression can be modelled from the younger ages up to 31.7 years old (phase 1); after this age of peak performance, we observe a decline (phase 2), as for many other disciplines.

This age-performance model has been previously demonstrated (Baker & Tang, 2010; Berthelot et al.,

2012; Guillaume et al., 2011) and our results are in line with previous findings on the average age of the top 50 marathon runners: 28.5 years \pm 3.8 years for women (Marc et al., 2018).

Age is a critical component for the return to performance based on the strong relationship between the two parameters. This relationship begins with a phase of exponential growth, reflecting the development of physical capabilities up to peak performance; followed by a phase of performance regression (Berthelot et al., 2019; Moore, 1975).

These results support the robustness of age as a predictor of performance development and demonstrate that maternity does not impact overall progression: when maternity takes place before the age of peak performance, the career still progresses, allowing most of the athletes to reach their best performance after maternity. When maternity takes place after the performance peak, it is followed by a decline in performance which, according to the models, would have occurred anyway (i.e. even without motherhood).

This physiological finding is consistent with another different study among elite French skiers (Haida et al., 2016). This study revealed that skiers who suffered an anterior cruciate ligament (ACL) rupture were able to reach new international podiums after injury; this, however, mostly depended on their age at the time of the rupture. Also, skiers who improved their performances after ACL rupture were young and had not yet reached the age of peak performance. Hence, under a pathological constraint, the main determinant of the capacity to surpass previous levels of performance also mostly relied on the age factor (Haida et al., 2016).

Length of maternity break and return to sports

Here we show a large variability in the maternity break durations, ranging from 9 months to 94 months. The return to international competitions after 9 months demonstrates that some athletes can quickly recover up to a highly competitive level. The variability of the break duration shows that it is a very individual decision or situation, with some athletes being able to reach again the international level after longer breaks. In fact, the athlete who stopped for 94 months gave birth to her first child at the age of 21.7; and to her second child at 24.7. She returned on track at the age of 29, and entered the all-time top 150 at age 33. She then realized her best performance at age 37.

While performance research on the postpartum period is limited, some studies shed light on this issue (Bø et al., 2017a). According to these, the time needed for postpartum soldiers to recover their pre-pregnancy

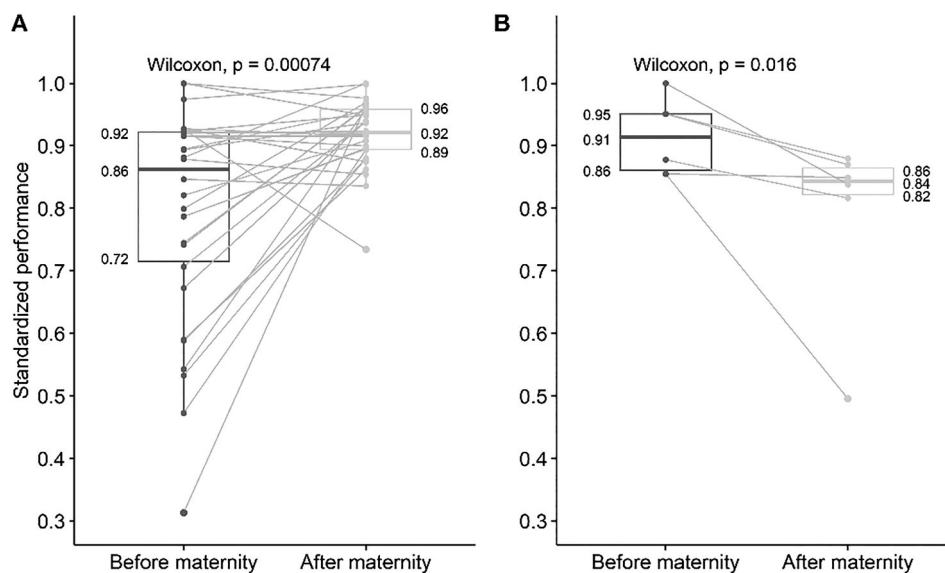


Figure 3. Comparison of the distribution of performance before and after first maternity break. (A) Group with a maternity occurring before the age at the estimated peak performance (31.7 yrs). (B) Group with a maternity occurring after age at the estimated peak performance.

physical capacity (Miller, Kutcher, & Adams, 2017) ranged between 2 and 24 months with a mean of 11 months. Women who experienced pregnancy after the age of 30 and older, and those who had disease and complications linked to their pregnancy needed more time to regain their pre-pregnancy performance level. These findings suggest that the return to physical activity from postpartum is an individualized process, that depends on age. This process can be brief, but age is one of the predominant factors for recovering after a maternity break. Few studies reported that rapid resumption of activities can be associated with adverse outcomes. Sundgot-Borgen et al. pointed out that most athletes did not have acute injuries during pregnancy or postpartum (Sundgot-Borgen et al., 2019). The majority of them (59%) reported returning to or outweighing to their pre-pregnancy level within 3–9 months after giving birth. The athletes that reported stress fractures during the postpartum period were related to an increase in training load early during the postpartum, with insufficient strength training during pregnancy, a history of relative energy deficiency in sport (RED-s) and/or possible inadequate intakes of calcium and vitamin D during pregnancy and breastfeeding period (Sundgot-Borgen et al., 2019). Athletes may then suffer postpartum setbacks due to fractures, which could induce further reduced overall training load, slower progression and utilization of alternative exercise modes (Solli & Sandbakk, 2018). One case study has scientifically followed the return to rigorous physical training of an elite athlete following childbirth;

Potteiger (Potteiger, Welch, & Byrne, 1993) monitored a 34-year-old elite marathon runner over the 16 weeks immediately following childbirth as she trained for the 1992 United States Olympic Marathon trial. They reported neither complications nor compromises to her health, as she resumed high intensity training, lost body weight steadily and improved her speed, maximal aerobic capacity, and lactate threshold.

A recent case study described the training of a world-class cross-country skier during pregnancy (at 35 years old) and postpartum. The study indicated that athletes can tolerate high training loads during the first and second trimester of pregnancy (with some adjustments of the training content) before a clear reduction of training volume during the third trimester (Solli & Sandbakk, 2018). This study provided an illustration of how to manage the return to post-partum exercise and then to performance, up to a gold medal at the World Championship, nearly one year after giving birth. An editorial published in 2022 (Donnelly, Moore, Brockwell, Rankin, & Cooke, 2022) propose to reframe return-to-sport postpartum. It promotes a proactive and whole-systems approach to perinatal athlete management and provide a timescale to support return-to-sport after maternity integrating individualized perinatal considerations within sporting organization.

The psychological dimension may be one of the reasons why some athletes do not lose pre-pregnancy performances. When you go from an athlete to a mother-athlete status, having a child involves significant changes in the everyday life. Although a mother-athlete

may sometimes feel guilty about returning to the field (Darroch & Hillsburg, 2017), most women, after having a child, increase their life-sport balance. Sometimes they can even better manage their discipline, training conditions, staff and emotional states (Martinez-Pascual, Alvarez-Harris, Fernández-De-Las-Peñas, & Palacios-Ceña, 2014). The planning management implied by motherhood can contribute to better performance when it consists of optimization of their training time in quantity and quality. This study also suggests that family time is better valued.

The trends brought forth by this study may help to eliminate remaining negative attitudes towards female athletes' choice to have children during their career and encourage coaches and support staffs to strategically incorporate the maternity break into a long-term training plan.

Limitations and strengths

Even though our data points to a full recovery of sports performance after a mid-career maternity leave, we cannot be certain of the number of women who decided not to come back after maternity, or could not come back to the international level. Also, based on a performance-focused approach and available public data, our study does not allow to understand how athletes recover their fitness or to identify factors that influence the recovery delay. Furthermore, due to the personal nature of the information related to pregnancy, we cannot assume that the women for whom we found no evidence of mid-career pregnancy did not have one. Therefore, we were not able to compare our sample to a control group and, instead, used the validated IMAP model in those for whom we have had a confirmed career pregnancy.

However, our study finds a large part of the cohort succeeding in coming back to the international level, and further outweigh their personal best after the maternity break. Thus, pregnancy may not increase the likelihood of prematurely ending a successful runner career.

Conclusion

Our main findings indicate that the world's most competitive marathoners can still perform at their best after pregnancy. The ability to return to and surpass the previous level of performance is primarily affected by the age at which pregnancy occurs, relative to the age of peak performance during career development. This question is part of the overall issue of balancing a high-level career with personal fulfilment, so that the former is not detrimental to the latter. Further research

on mid-career maternity in several sports and disciplines may help to better understand the full impacts of pregnancy on an athlete's career and shed light on the issue of life balance among elite female athletes.

Acknowledgements

The authors wish to thank INSEP teams for their full support.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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