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Pregnancy and returning to high-level sports: a retrospective study of Olympic athletes from Italian teams

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ABSTRACT

Objective. Based on the experience of elite athletes from Italian Olympic teams, this study aims to describe their pregnancy and training during this period and their return to top-level sport.
Materials and Methods. A questionnaire was administered to athletes who had participated in the past five Olympic Games, starting with Sydney 2000. The questionnaire was divided into four parts (pregnancy, birth, postpartum, and return to competition) and administered by medical personnel.
Results. Fifty-five athletes from national Olympic teams were included in the study. Average age at conception was 31.0 ± 4.3 years. The disciplines were classified as skill, power, mixed and endurance. Weigh gain, duration and quality of sleep, and urogenital ailments were recorded. The number and type of training sessions during pregnancy and post-partum were evaluated. Athletes returned to competition at an average of 7 months after the birth of the child (range, 1-36 months); 50.6% of the athletes returned to international-level competitions.
Conclusions. This study shows that athletes continued to train during pregnancy and returned to competition after birth, answering questions increasingly asked by pregnant women: is it possible to continue to practice sport, following specific training sessions and to return to compete at a high level?

INTRODUCTION

Purpose of the study

The world of medicine and the world of sports have recently emphasized the importance of studies on the effect of sports activities on pregnancy and the return to sports after childbirth, as described in several articles by the International Olympic Committee Expert Group [1-4]. The experience of elite athletes on Italian Olympic teams and analyses of specific information about the type and frequency of exercises carried out during pregnancy, the health and management of the infants after birth and the early return to sports by the mothers can improve our understanding of this poorly studied topic and help draw conclusions that are valid for all women of childbearing age who desire to have a child. The data provided by this study can help both high-level athletes and women who participate in non-competitive sports to understand that if a woman is well supported by medical and athletic staff, they can train safely during and early after giving birth and have the benefits of exercise throughout.

Guidelines on exercise and pregnancy encourage women to maintain an active lifestyle during and after pregnancy [5] and our study shows how, with the support of a dedicated team, athletes who plan on returning to competitive sports after giving birth take a different approach, adopting a more planned and professional exercise routine both during pregnancy and after childbirth. Their experience can lead the way to updated and more precise advice. Instructions concerning exercise in pregnancy are often unclear, and a high percentage of pregnant women do not exercise or follow the guidelines for physical exercise [6] and may be more motivated to make diet or lifestyle changes [7]. This behaviour can increase the risk of potentially serious situations, including excessive weight gain, gestational diabetes mellitus and other diseases related to pregnancy [6] as well as excessive weight of the infant at birth, *etc*.

Different studies show that exercising during pregnancy in the absence of disease or an at-risk pregnancy helps women maintain a strong, agile body, control their weight, and relieve tension and anxiety, offering a healthier approach to this complex period. However, an increasing percentage of women wish to continue to exercise safely throughout pregnancy, and they need precise answers on how to do so, and on how soon and under what conditions they can start exercising again after giving birth.

Although not rare in the past, the number of athletes who plan pregnancy during their career in competitive sports has increased. However, few studies have been conducted globally on women who adjust their training regime with the support of a team that includes their gynaecologist, fitness coach and sports medicine staff. The data collected in this study, with the support of the existing bibliography, can help answer questions that are increasingly asked by pregnant women: what sports, exercises and activities they can participate in – with information about intensity and duration – without putting the health of the mother or the baby at risk? Should any particular sports or exercises be avoided? When can they begin training and competing after giving birth?

With improved training and injury prevention, athletes in Italy and around the world can enjoy increasingly longer careers. Italian athletes generally compete into their thirties and sometimes beyond, and many wish to become mothers and return to competitive sports after giving birth. Athletes in competitive sports are known to maintain a higher level of training during pregnancy compared with active women and to return to practice earlier after giving birth, which often has a favourable impact on performance. It is increasingly common to see new mothers climb the global rankings and improve their performance. One recent example is the semi-finals of the US Open in tennis; three of the four athletes were mothers.

The need for new studies and clarity stems from past documentation, which at times suggested that elite athletes might be at risk of experiencing critical circumstances, such as a greater danger of miscarriage, premature birth, prolonged labour, lower birth weight, pelvic floor dysfunction, back pain and other issues, compared with less active women. The current approach almost always suggests that, when there are no medical or obstetric contraindications, all pregnant women should participate in about 150 minutes of moderate to intense aerobic exercise each week. However, there are no specific guidelines for high-level athletes, in terms of either the type or quantity of exercises recommended, and therefore the information and recommendations are mainly based on the opinions of experts or trainers.

The world of sports and especially the Olympic movement has actively intervened in this area. Sports are considered as much a tool for growth, health and integration as an opportunity for competition, and therefore, having noted the lack of specific evidence-based guidelines, the International Olympic Committee created a team to review the existing medical literature and published five articles on the topic, which serve as the starting point for our study [2].
By considering the typical changes that accompany pregnancy and their effects on athletic activities, this study evaluates the data from interviews with elite athletes and outlines some features that allow physical activity before and after childbirth, with the assurance of the most recent literature on the topic. The purpose of this study is to clarify whether pregnancy in athletes can be described in the same terms as pregnancy in healthy physically active women, note the type and quantity of training recommended in the three trimesters and outline the journey to resuming physical activity. The results of this study can help identify more specific guidelines for physical activity in non-athletes before and during pregnancy and after delivery, accounting for the health and habits of the woman and contributing positively to the physical and mental health of both the mother and child.

MATERIALS AND METHODS

Participating athletes

For this study, the Italian National Olympic Committee granted access to the CONI Institute of Sports Medicine, where athletes who have been identified through the Olympic preparation process as potential participants in Olympic Games, receive complete annual check-ups, including functional check-ups. All the Olympic Federations were informed about the study, with the objective of administering a questionnaire to athletes who had participated in the last five summer and winter Olympic Games and had carried a pregnancy before returning to competition. A team was set up consisting of three doctors specialized in sports medicine, one gynaecologist, two fitness coaches and one statistician. To select participants for the study, the biographies of the Italian team members who participated in each of the games were examined, and federation doctors and head offices were asked to contribute. Criteria for inclusion were participation in the Olympic Games, having had a baby and returning to competitive sports. Exclusion criteria were failure to respond to the questionnaire or incomplete response.
The study design was evaluated and approved by the Review Board of the Institution of Sports Medicine and Science. All participants were fully informed of the type and nature of the evaluation and signed the consent form, according to Italian law and the Institute's policy. All clinical data from the study population are maintained in an institutional database, in compliance with privacy legislation.

Questionnaire and telephone interview

In 2018, we began surveying Olympic athletes who had given birth before competing between the Sydney Olympics in 2000 and the Olympics in Rio de Janeiro (2016), relying on data stored at the Institute of Sports Medicine and information received from federation doctors. Our main goal was to investigate the training of pregnant athletes who wanted to return to competition, therefore we excluded those who left competitive sports after giving birth. We identified 55 athletes who carried their pregnancy to term and continued to train during the pregnancy, albeit with a special programme, and returned to competitive sports after childbirth.
A questionnaire was administered by medical personnel both digitally and by phone interview consisting of four parts: pregnancy, birth, post-partum, and return to activity. The first section, related to pregnancy, started by collecting data on the athletes' personal information: age at conception, Olympic speciality (skill, power, endurance or mixed) and whether the pregnancy was planned or unexpected. Subsequent questions asked whether they continued to compete, the intensity of training, the athlete's health in terms of weight gain, fluctuations in blood pressure, injuries, presence of urogenital disorders, duration and quality of sleep, diagnostic tests received, and any medicines taken in each trimester.
The second section collected information about the delivery (natural, caesarean, induced) and any complications (laceration, episiotomy), as well as the infant's clinical record: weight and height, Apgar score, feeding (breast milk, formula, mixed), and any complications (mastitis, engorgement, rhagades).
The data for the third section was provided by the mothers, and from doctor reports and team reports

and covered four phases in the post-partum period: 0-3 months, 4-6 months, 7-9 months, and 10-12 months. For each phase, the mothers were asked to specify their weight, the length and weight of the child, how the child was fed and whether the mother had returned to sports (movement, aerobic training, anaerobic training, abdominal exercises, upper limb exercises, lower limb exercises, specific technical exercises).

In the fourth section, athletes were asked about their return to competitive sports and their participation in competitions. They were asked how old the child was when they started to compete again and to provide information about the first five competitions entered after giving birth: weight of the mother, age, diet, child management, results they achieved and which of these was their best based on their own evaluation.

Statistical analysis

Categorical variables are expressed as frequencies (n) or proportions of each category (percentage), and continuous variables are summarized as medians and range (minimum-maximum) or interquartile range (IQR, 25%-75%) when appropriate. Chi-squared tests (or Fisher exact tests) compared dichotomous variables. Mann-Whitney U tests were used to compare continuous variables because some continuous variables exhibited skewed distributions on visual inspection, and the Kolmogorov-Smirnov test indicated non-normal distributions. Statistical tests were two-sided and a P-value < 0.05 was considered significant. Statistical analyses were performed using SPSS software (SPSS, Cary, NC, USA).

RESULTS

Fifty-five athletes were included in the study. Average age at the time of the study was 40 years and average age at conception was 31.0 ± 4.3 years (range, 19-41 years), which is largely in line with the general population in Italy; the average age of first pregnancy in Italy is close to 32 years, an increase of nearly 12 months compared with 2008 (source: ISTAT). In the rest of the European Union, first-time mothers are between 20 and 29 years old. Average weight at conception was 58 kg.

Athletic specialities

All the athletes were part of the national Olympic team and participated in Olympic Games, starting with Sydney 2000. Their disciplines were classified under the headings of skill, power, mixed and endurance [8]. The athletes, members of the national Olympic delegation, belonged to different federations and participated in different sports, distributed as follows: 40% skill sports, 30.9% endurance sports, and 14.5% each for power and mixed sports (**Figure 1**).

Sport Disciplines

Skill		Power		Mixed		Endurance	
Heart rate	+/++	Heart rate	++	Heart rate	++/+++	Heart rate	+++
Blood pressure	+	Blood pressure	+++	Blood pressure	++	Blood pressure	++
Cardiac output	+	Cardiac output	++	Cardiac output	++/+++	Cardiac output	+++
Volume of training	-	Volume of training	+	Volume of training	++	Volume of training	+++
Cardiac remodeling	-	Cardiac remodeling	+	Cardiac remodeling	++	Cardiac remodeling	+++
• Archery • Car/ motor racing • Curling • Equestrian • Golf • Sailing • Shooting • Table Tennis		• Alpine skiing • Bobsleigh • Discus/javelin • Shot-puffing • Snowboarding • Sprinting • Water siding • Weightlifting • Wrestling		• Basketball • Cricket • Fencing • Football • Handball • Ice/field hockey • Rugby • Soccer • Tennis • Water polo • Volleyball		• Canoeing • Cross-country skiing • Cycling • Mid-long distance swimming • Mid-long distance running • Mid-long distance skating • Pentathlon • Rowing • Triathlon	

Figure 1. *Categories of sports disciplines.*

Pregnancy-related trends

The physiological changes caused by pregnancy are largely known, and the athlete and her staff must take these into account when deciding about continued participation in sports while pregnant. This is especially true when, as was the case with the athletes, the pregnancy is planned; 67.3% of the pregnancies studied were planned, presumably so they would fit between the most important competitive events.

Weight gain is often of great significance for the athlete, whether the athlete participates in a sport with weight categories or not, even just for the psychological impact. The dietary needs for a healthy pregnancy, which increases the demand for energy, liquids and certain nutrients, are well known. These aspects must be considered when the energy required for physical activity is added to the energy specifically needed for the development of the foetus, placenta, amniotic fluid, uterus, adipose tissue, and increased volume of blood and extracellular fluid [9]. The additional energy needed by pregnant women with good weight gain (defined as an average weight gain of 12 kg from conception to childbirth) is estimated at 90 kcal/day for the first trimester, 287 kcal/day for the second trimester and 466 kcal/day for the third trimester [10]. Energy expenditure remains increased in elite athletes who continue to work out during pregnancy, and the intake required to meet total energy demands will depend on the type, frequency, intensity and duration of the activities carried out.

The weight of the athletes increased with each trimester. Most of them increased from 7 kg to more than 10 kg, which is in line with the guidelines. The average weight increase at childbirth was 13.8 kg (minimum, 5 kg; maximum, 30 kg). As a rule of thumb, a woman of average weight should gain about 12 kg [11]. Considering the lifestyle of the athletes and the level of daily exertion, sleep is especially important for recovery, especially during training periods. For the athletes in our study, the hours of sleep increased with no differences noted in terms of quality, providing them with proper recovery. With regard to overall health, the women were asked about urogenital ailments, which can occur during pregnancy; 96.4% of athletes stated that they had no such complaints. No cases of pre-eclampsia were reported.

Athletes are also careful about taking pharmaceuticals, especially elite athletes who undergo anti-doping tests at competitions and randomly at other times. Of the athletes surveyed, 92.7% stated that they had taken no pharmaceuticals for the duration of the pregnancy. Another aspect surveyed in the questionnaire, partly in relation to continued workouts, was the occurrence of any injuries. Of the Olympic athletes we interviewed, 98.2% stated that they had not experienced any injuries.

Training during pregnancy

A large part of our questionnaire was dedicated to a retrospective analysis of how athletes trained during and after pregnancy. These were national athletes, therefore training before the pregnancy consisted of at least one session per day, with competitions at the weekend.

Number of training sessions

The number of training sessions remained largely the same up to the end of the second trimester, when they decreased significantly, albeit without coming to a halt (**Figure 2**). Specifically, the number of training activities and different programmes decreased, whereas anything that could be considered movement, *i.e.*, walking and slow running, tended to increase. Athletes tended to suspend competitions near the end of the first or at the start of the second trimester; however, they did not suspend physical activity at this time. Non-competitive activity increased, as is reflected by the increased number of training sessions indicated as "movement activities" (**Figure 2**). Therefore, in confirming that athletes maintain a certain level of training but modify the type of training, the literature provides greater clarity about the nature of the workouts.

Strength training

Negative health effects are not reported in the literature for light to moderate training with free weights or machines [12-15]. The strength of apparently healthy pregnant women who participated in strength training at least twice per week for 12 weeks during pregnancy increased significantly (36% for leg press, 39% for leg curl, 39% for pull down, 41% for lumbar extension and 56% for leg extension). Training was associated with a 14% increase in lumbar resistance [16]. However, this was light strength training and cannot be compared with the training that high-level athletes undertook before the pregnancy.

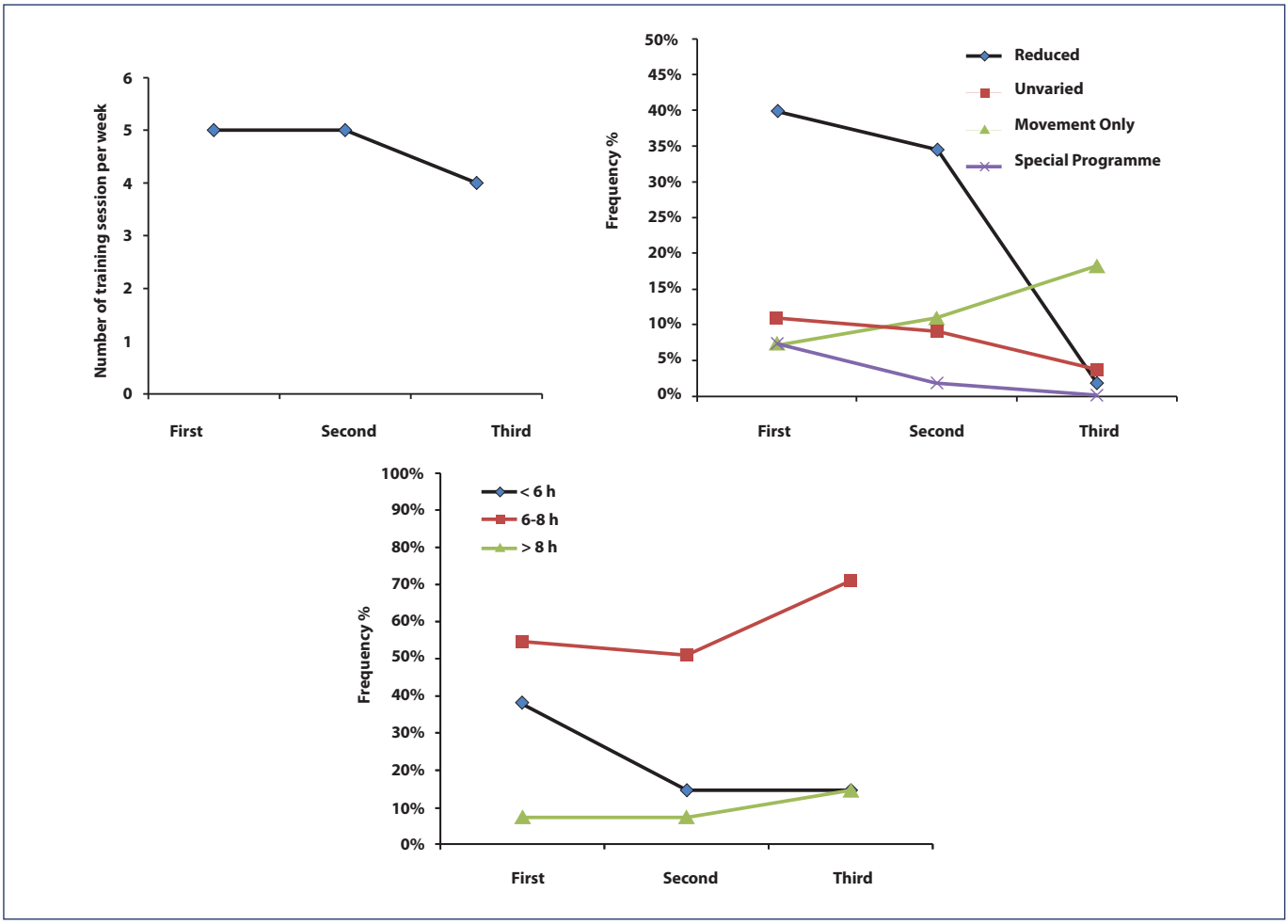

Figure 2. *Training during pregnancy.*

Resistance

Studies on women who participated in amateur sports did not reveal differences in aerobic capacity (absolute VO_2 max) tested during the last 2 months of pregnancy and again 6-8 weeks after childbirth [17], whereas women at a higher athletic level, with moderate to increased exercise levels during and after pregnancy, saw a 5%-10% increase in VO_2 max after pregnancy [17, 18].

Birth

Of the athletes surveyed, 71.2% had a spontaneous delivery, 7.7% had induced delivery, and 21.2% had a caesarean delivery, which is less than the incidence of caesarean delivery in Italy at 35.7%, the highest in Europe [19]. This seems to be consistent with the specialized literature, which states that evidence on the risk of caesarean delivery in elite athletes is insufficient and that, because they are more likely to have a normal body mass index, the risk of caesarean delivery should be lower. The literature is not unanimous on this point. Two meta-analyses of the general population indicated a reduced risk of caesarean delivery in those who carried out aerobic activity compared with controls [20, 21], whereas other meta-analyses did not show a reduced risk [22].

Regarding spontaneous delivery, the idea that intense physical exercise increases the muscle tone of the pelvic floor (hypertonia of the elevator ani or perineum of the athlete), which might lead to prolonged labour and perineal trauma [2] remains widespread. In the general population, about 85% of women experience perineal trauma during childbirth. The incidence of perineal injury is 6.1% in primiparous and 1.7% in multiparous women. Episiotomy seems a particularly protective practice in eutocic deliveries. The incidence of episiotomy in the general population varies from 60% to 70% of natural births. Our data confirm that, of the athletes who gave birth naturally, 48% maintained perineal integrity and 13.6% has an episiotomy.

The newborn

When an athlete plans a pregnancy with the goal of continuing to compete after giving birth, one of the most frequent questions is whether continuing to train during pregnancy might somehow be harmful for the child. Even though the benefits for the health of the mother are well known, there is long-standing concern about the negative effects that maternal exercise might have on the developing foetus, childbirth and the outcome at birth.
The main concern is associated with the selective redistribution of blood flow to the mother's muscles that are being exerted at the expense of foetal oxygenation, with resulting changes in the foetal heart rate and the threat of spontaneous abortion. Equally concerning are the implications for uterine blood flow and the reduced availability of nutrients, which might have an impact on foetal weight, a topic that seems to affect elite athletes in particular.
In our study, the average Apgar score for the newborns of the 55 elite athletes interviewed was 9.8. Few studies (none in elite athletes) and with a low number of participants have evaluated the impact of exercise on Apgar scores. Two randomized studies that included inactive and previously sedentary women who had received both habitual assistance and a structured exercise schedule published conflicting results. In one study, no difference was noted in the average Apgar score at 1 minute (7.5-1.3 *vs* 8.0-0.8, p = 0.31) or 5 minutes (9.4-0.6 *vs* 9.6-0.4, p = 0.08) between the control group and the active women [23]. The other study showed higher Apgar scores at 1 and 5 minutes for the group that exercised (p = 0.036 and 0.01, respectively) [24]. The average weight at birth of the newborns in our study was 3.2 kg (minimum, 2.1 kg; maximum, 4.9 kg) and the average length was 51 cm (minimum, 45 cm; maximum, 58 cm).
The concern that redistribution of blood flow might even mildly harm the health of the unborn child seems to have been suitably addressed by a broad Cochrane Review of 14 studies on 1014 women [25], which did not report any significant change in weight at birth as a result of physical exercise by the mother during pregnancy. On the contrary, as was true in our study, moderate intensity exercise can reduce the risk of children being large or small for gestational age, and lower birth weight reflects a lower fat mass but higher lean mass for infants with active mothers compared with infants with sedentary mothers [26]. Our study showed a hospital stay of 3 days on average (minimum, 2 days; maximum, 7 days). Feeding during the hospital stay was 90.4% breast, 3.8% mixed, 1.9% formula, and 3.8% artificial milk. The data from our study are provided in **Table 1**.

Post-partum

After childbirth, the athletes' weight loss was linear and returned to the level at conception within 12 months (**Figure 3**). To achieve these results, besides starting to train again, the athletes combined a controlled diet with specific dietary supplements. To avoid excess weight loss, athletes who are both breastfeeding and training should have a diet that adequately meets their needs in terms of energy and nutrition.
Of the athletes surveyed, 63% stated that they had no trouble breastfeeding, 60% used supports and 34.5% stored milk for an average 40.2 hours (**Figure 4**). With this management and diet, infants showed regular growth in terms of both weight and height (**Figure 4**).

Training sessions

The athletes in the study began to increase their weekly training in the first trimester after giving birth, with a significant increase after the first 3 months (p = 0.033), when 50% of the athletes stated that they were still breastfeeding and 30% stated that they were using formula (**Figure 5**). With regard to the types of exercises introduced post-partum, between 0 and 3 months, there was an increasing frequency – in terms of training sessions – of exercises for the lower limbs and abdominal wall, followed by walking and stretching, with just two sessions per week of aerobic and anaerobic training. This mix of exercises changed between the 4th and 6th month when the frequency of walking and anaerobic and aerobic work increased (with the former still prevalent over the latter). Abdominal muscle activities remained constant and activities for the lower limbs decreased. Between the 7th and 9th month, work on the abdominal wall and core stability was prevalent, aerobic work and work on the upper and lower limbs increased, and the frequency of anaerobic work remained the same. At 1 year after childbirth, the frequency of stretching and core stability exercises was predominant, and the frequency of aerobic activity, anaerobic activ-

Table 1. *Characteristics of childbirth and newborn.*

	Parameters	Median	Min	Max	IQR 25%	IQR 75%	cat-0	cat-1	cat-2	cat-3	cat-0	cat-1	cat-2	cat-3
Childbirth	**Type of delivery** Spontaneous = 0 Caesarean = 1 Induced = 2	-	-	-	-		37	11	4	-	71.2%	21.2%	7.7%	-
	Weight at birth	73.8	52.0	103.0	64.5	84.5		-	-	-	--	-	-	-
	Increase from the start of pregnancy	13.8	5.9	30.0	9.3	17.5		-	-	-	--	-		-
	Perineum Laceration = 0 Intact = 1 Episiotomy = 2	-	-	-	-		20	25	7	-	38.5%	48.1%	13.5%	
Newborn	**Apgar**	9.8	8.0	10	--	--		-	-	-.				.
	Weight	3.2	2.1	4.9	3.0	3.6		-	-			-		--
	Length	51.0	45.0	58	50	54		-	-		-	-		-
	Sex M, F = 1	-	--	--	--	-	23	27			46.0%	54.0%		-
	Hospital stay days	3.0	2.0	7.0	-	-	-	-			-	-		-
	Feeding during hospital stay Breast milk = 0 Mixed = 1 Formula = 2 Artificial milk = 3	-	-	-	-	-	47	2	1	2	90.4%	3.8%	1.9%	3.8%
	Months of exclusive breastfeeding	5	1	18		--					-	-	-	-
	Difficulty breastfeeding no = 0 yes = 1	-			-	-	35	20			63.6%	36.4%		-
	Support used no = 0 yes = 1		-		-	-	22	33			40.0%	60.0%		
	Milk stored no = 0 yes = 1	-	--		-	-	36	19			65.5%	34.5%		-
	Milk storage time	40.2	1.0	320			--	--			--	--		--

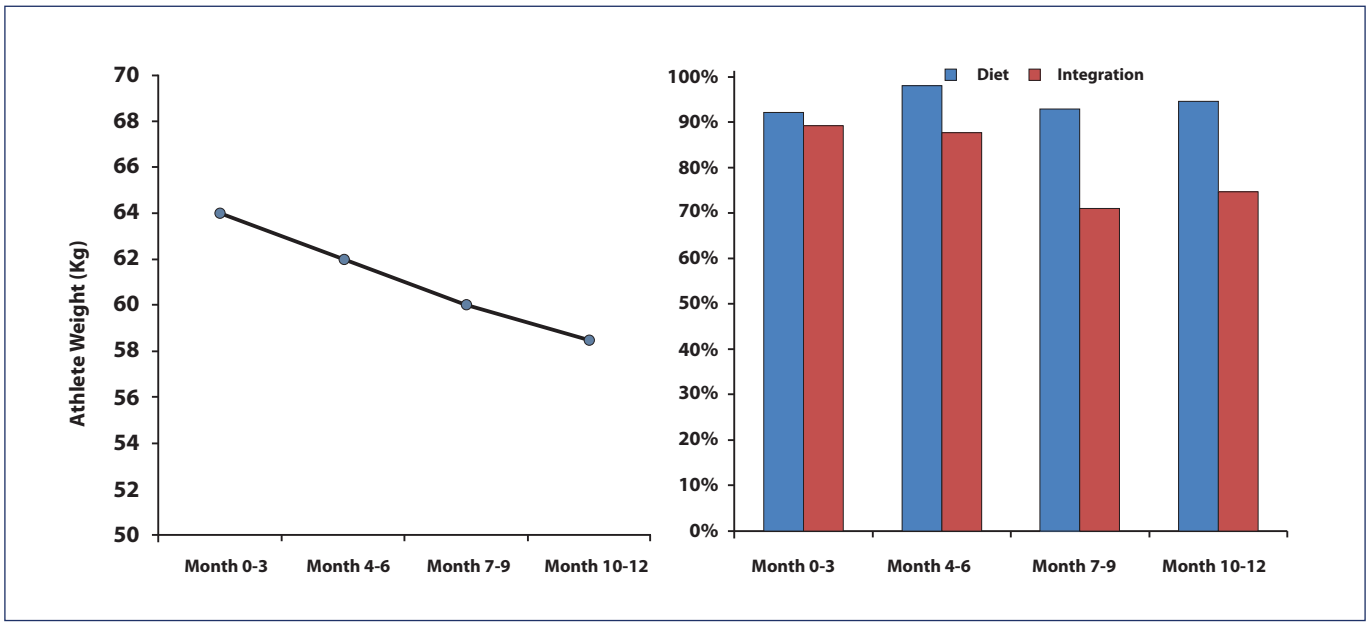

Figure 3. *Athletes' loss of weight and alimentation.*

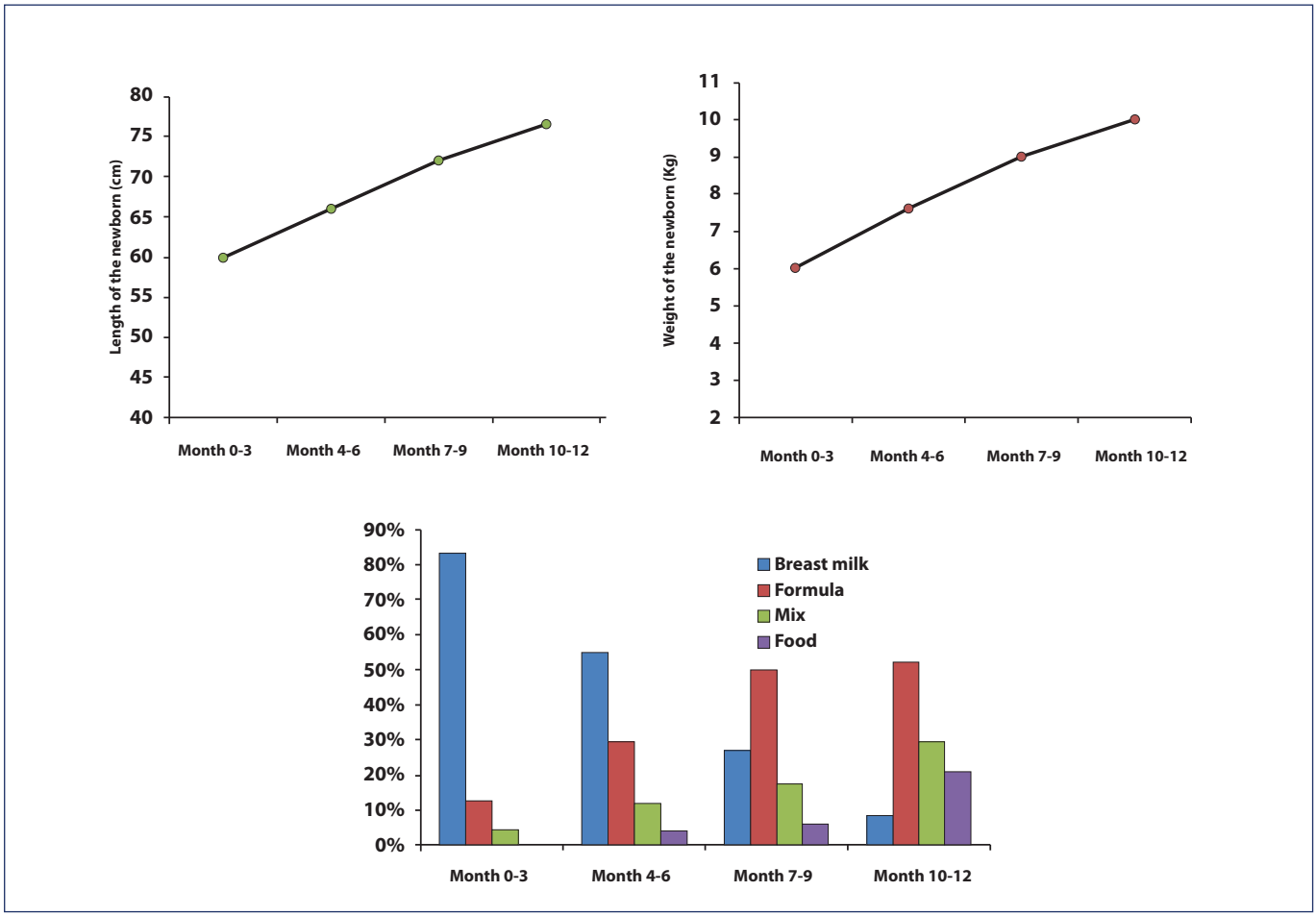

Figure 4. *Newborn growth and alimentation.*

ity and lower limb exercises remained constant (**Figure 5**).

Resuming competitive sport

On average, athletes returned to competitive activity 7 months after the birth of the child (minimum, 1 month; maximum, 36 months); on average, the first competition occurred 1 year after childbirth (minimum, 3 months; maximum, 72 months). Athletes achieved stable weight at the same time as they re-

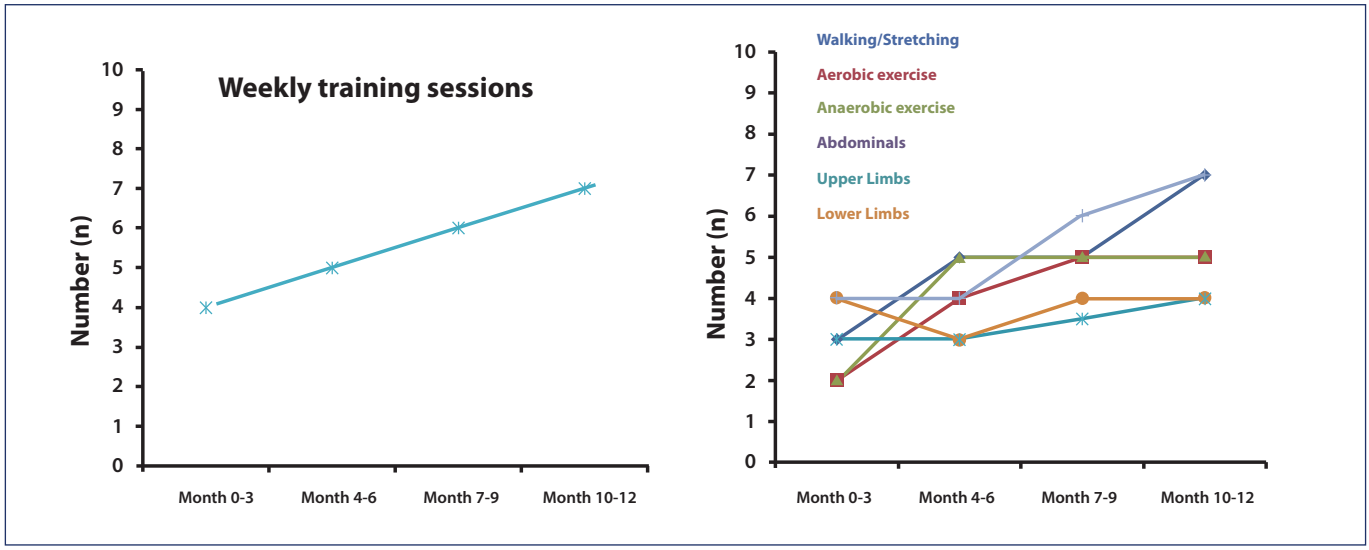

Figure 5. *Training post-partum.*

turned to competing; weight did not vary from one competition to the next. The average stable weight was 57+18 kg. At the return to competitive sports, 44.9% were feeding their children a normal diet, 20% were using artificial milk, 18.4% were using breast milk and 16% were giving a mixed diet. At the time they achieved their peak result, 44.9% of mothers were using a mixed diet for their children, 40% a normal diet, 12% were still breastfeeding and 4% were providing artificial milk.

To evaluate the return to pre-pregnancy levels, we looked at their first five competitions and the final results achieved in their career. The main concern athletes have when they decide to undertake a pregnancy is being able to return to the same competitive level. Our study shows that 19.5% returned to compete at World Championship level and 17.1% competed in the Olympics. Another 14% returned at the European level, and 17% returned to compete at the national level. Therefore, 50.6% of athletes returned to international-level competitions (**Figure 6**). Their peak result was achieved on average 18 months after giving birth (minimum, 5 months; maximum, 96 months). On returning to competitions, 40% of athletes returned to the podium and 30.6% returned to win a gold medal (**Figure 6**).

Life as a mother and an athlete is certainly more complex, not only due to the need to regain fitness and ensure the healthy development of the child but also because of the organizational requirements of competing at the international level. When we investigated how this might impact athletes as they strive to achieve new objectives, we found that upon returning to competitions, 44% of mothers left their children with grandparents, 26% with the father and 8% with a babysitter. At the point when they achieved their best results, 42% of mothers still relied on grandparents for help with their child, 14% relied on a babysitter, 8% were helped by the child's father and 36% found other solutions.

DISCUSSION

Our study on 55 Olympic athletes who had a child during their competitive career showed that athletes can continue to train during pregnancy and return to training soon after, they give birth to healthy children and return to compete at the international level. It is clear that the athletic activities of the athletes surveyed, as well as the nature of their training sessions before childbirth, were many and varied, so they cannot be considered a uniform group. Given the different ages, diverse provenance and variety of training methods, as well as the na-

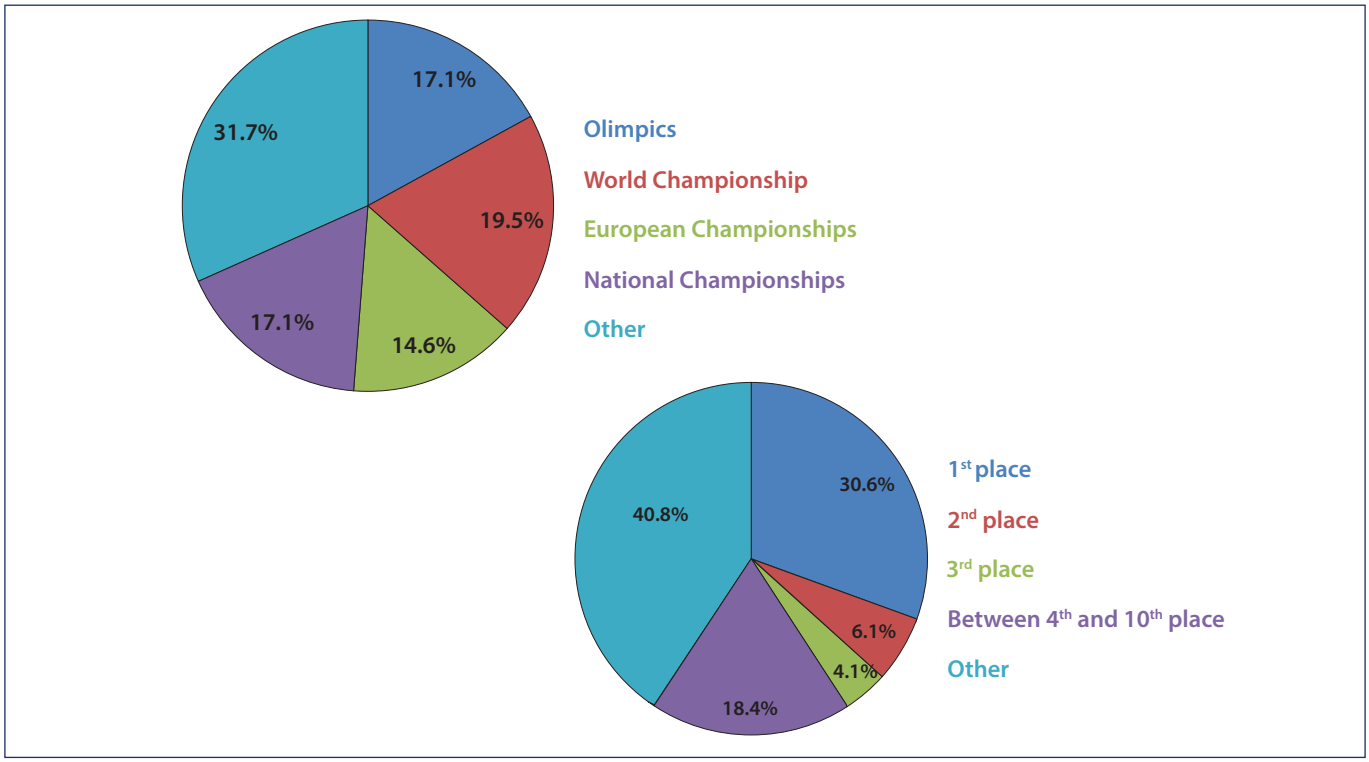

Figure 6. *Resuming competitive sport.*

ture of the disciplines, the population surveyed in this study can be considered representative of the national population; key differences are the quantity and quality of training before pregnancy and the psychological drive to recover fitness and return to the previous level of performance.

Adequate information about the possible effect of pregnancy on performance is crucial to making an informed decision. High-level athletes who have a physiological pregnancy without complications should be reassured that they can continue to train, although some adjustments to the intensity and type of activity may be needed.

As was true for most of the athletes, planning the pregnancy and birth to fit between important competitions (*e.g.*, the Olympic Games) may be possible, and there is evidence that many athletes achieved the same level, or even improved their performance, after the pregnancy and birth of their child [27].

Where there are no contraindications for the mother or child, the prescription of physical exercise during pregnancy follows the same principles used for the general population, with the exception that pregnancy produces significant anatomic, hormonal, metabolic, cardiovascular and pulmonary changes, which must be taken into consideration when prescribing a given exercise.

Athletes reduce the frequency of training during pregnancy, but the biggest change is in the types of exercises carried out. Resistance exercises, if carried out on suitable surfaces and at moderate levels, based on the previous level of training, even when extended into the third trimester at a greatly reduced intensity, produce measurable improvements in the physical fitness of pregnant women [28]. For high-level and elite athletes, an in-depth clinical evaluation is needed to rule out any medical or obstetric concerns that might require complete abstinence from exercise or a change in the workout routine [1] to adapt to the guidelines of the American College of Obstetricians and Gynaecologists. These factors may not be present initially and can occur at any moment during pregnancy, changing the risk level. They must always be taken into consideration and monitoring must be shared with the athlete and her staff.

The sports to be avoided during pregnancy can be subdivided into those with a risk of trauma (*e.g.*, due to a collision or hitting one's head or falling) and those with physiological risk factors (*e.g.*, scuba diving). Maternal trauma may result in sudden or chronic foetal hypoxia. Creating an exhaustive list is impossible, but examples include bobsleighing, tobogganing, horse riding, pole-vaulting, ice hockey and downhill skiing. Due to the physiological risk, women should refrain from scuba diving, because the foetus is not protected from decompression problems and is at risk of malformation and gas embolism [29]. Olympic contact sports such as wrestling, boxing, judo, taekwondo, rugby and ice hockey should be avoided during pregnancy, although non-contact training can be continued. The following Olympic sports should also be avoided, especially during the second and third trimesters: football (soccer), handball, basketball, equestrian sports, field hockey, trampoline, artistic gymnastics, underwater sports, BMX and mountain bike cycling, volleyball, some athletics events, downhill skiing, freestyle skiing, ski jumping, tobogganing, bobsledding, skeleton racing, snowboarding, short track speed skating and some artistic skating events that pose a risk of traumatic contact with other athletes or with the environment. In these cases, too, training may continue according to the indications provided previously.

If athletes are permitted and can continue resistance training at a moderate level throughout gestation, they can expect their maximum aerobic capacity (VO_2 max) after giving birth to be similar to the pre-pregnancy level. Changes to the curvature of the spine during pregnancy and frequent or prolonged postures (that cause pain) may affect the pelvic ligaments, causing pain. Increased awareness and the perception that athletes have of their bodies must help them avoid useless loads and stress on joints, ligaments and muscles, during both exercise and everyday activities.

In addition to the evidence provided by our data, the studies used as a reference for this article indicate that the aerobic fitness of a woman will remain the same or improve slightly during pregnancy if she continues to exercise, maternal symptoms permitting. Athletes, and active women in general, need guidance in selecting the type, frequency and intensity of activity, and risk evaluation must be constant. Different systems can be used such as that shown in **Figure 7** [30]. Healthy women with a single, uncomplicated pregnancy are at low risk of maternal (or foetal) adverse events related to physical exercise when they participate in low to moderate-intensity activity. Furthermore, inactivity before pregnancy should not be a hindrance to physical exercise when women are classified

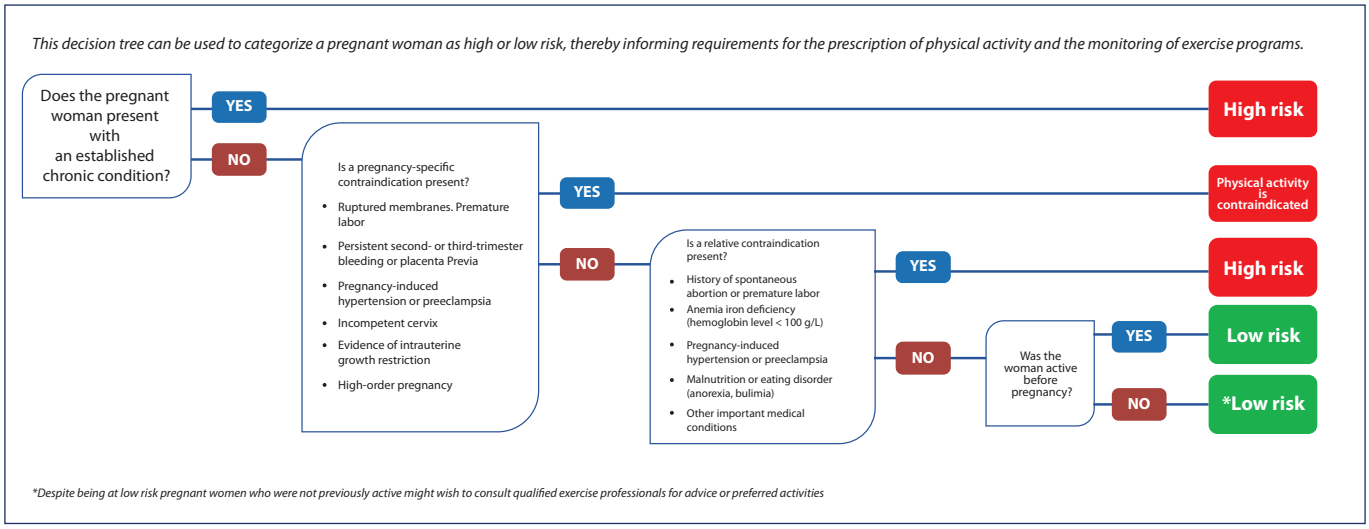

Figure 7. *Clinical decision tree for assessing the risk of adverse events during physical activity in pregnant women.*

as being at low risk. In addition, recommending guided physical activity may serve as a stimulus to improve maternal-foetal health and reduce excess weight gain. Women must receive support and be encouraged to participate in physical activity, being careful to recommend exercises that minimize the risk of loss of balance, trauma to joints and ligaments, and avoiding activities that might cause foetal trauma. It is important for the health of the woman and the child that physical activity is prescribed through cooperation with qualified professionals, as is the case with the staff of high-level athletes.

With regard to the risk of spontaneous abortion, a systematic review [20] concluded that light to moderate physical activity does not increase the risk of spontaneous abortion and may decrease the risk. Special attention is needed during the implantation phase to avoid intense and demanding exercises, especially in at-risk situations [31].

In the absence of further studies on elite athletes, we maintain that athletes who are planning a pregnancy can consider limiting the intensity of their high-impact training routine in the week after ovulation and abstain from repetitive heavy lifting during the first trimester of pregnancy. Exercise during pregnancy has a 31% lower risk of having a newborn that weighs > 4000 g or at > 90th percentile for gestational age (95% confidence interval, 0.55-0.86). To achieve that objective, in the absence of contraindications, an exercise regime with two to three 30-minute training sessions per week can be recommended. When exercising, mothers should be careful to avoid situations such as certain outdoor temperatures, intense physical strain and clothing that may lead to an excessively high body temperature. Hyperthermia must especially be avoided during the first trimester. Physical exercise at 60%-70% of VO_2 max does not increase internal body temperature to more than 38 °C. Moderate exercise during pregnancy will not raise internal body temperature above this limit.

Training in a static supine position requires special attention and if side effects occur, such as dizziness, the activity must be interrupted, because there is a risk of reducing venous return and diminishing uterine blood flow. This situation tends to arise after 28 weeks. To reduce the potential risks, exercises that are normally carried out in a supine position may be modified with the upper body at a 45° incline or by completing the exercises in a lateral, sitting or standing position. Some studies do not note any negative effects of physical exercise in a supine position for 2-3 minutes at a time [32, 33].

Strength training must be guided and executed with special attention to the respiratory cycle (avoiding apnoea) because the Valsalva manoeuvre used during weight training causes a rapid increase in blood pressure and intra-abdominal pressure and can temporarily reduce the flow of blood to the child [34, 35]. Working incorrectly with excess loads causes other side effects, including an increased risk of urinary incontinence or pelvic organ prolapse during or after pregnancy [36] due to the increased pressure on the pelvic floor. On the other hand, many studies show that strengthening the muscles of the pelvic floor during pregnancy can treat and prevent urinary incontinence during pregnancy and after childbirth. Maximal contractions of pelvic floor muscles, in series of 8

to 12, three times per day are recommended. Muscle training exercises for the rehabilitation of the pelvic floor during pregnancy have been shown to reduce the duration of the first and second phase of labour without having a negative effect on childbirth [37]. Overall, athletes should be advised to pay attention to technique and safety, taking any necessary precautions to ensure that movements are executed properly.

For high-intensity resistance training, both athletes and active women need to be advised to measure the intensity of the workout based on perceived strain or effort, being careful to limit perceived strain. Elite athletes are advised to refrain from training at an intensity > 80% of their VO_2 max.

Resuming sports after giving birth must be seen as a journey consisting of three levels: participation in training or sports, but at a level below the pre-pregnancy level; return to the specific sport but without performing at the previous level (some athletes may be satisfied with this level after giving birth); return to full performance, *i.e.*, the athlete has gradually returned to her sport and is competing at pre-pregnancy level or higher.

In terms of resistance training, women who have exercised regularly, at least at a moderate level during pregnancy, can expect their VO_2 max to return to the pre-pregnancy level or even higher after giving birth. Resistance training should begin gradually in the post-partum period. Low-impact activities such as cross-country skiing, fast walking and low-impact aerobics place little pressure on the pelvic floor and can be started immediately after giving birth. Strength training in the post-partum period must be introduced gradually and with great care – especially for the pelvic floor – carrying out pre-contraction of the pelvic floor muscle and maintaining the contraction during exercises that cause higher levels of intra-abdominal pressure (*e.g.*, bench press, heavy abdominal workout, leg press and squat). Special care must also be taken with the core, because abdominal, dorsal and lower back muscles have been placed under great strain since the second trimester.

We found that athletes chose to breastfeed, and sometimes continued to do so even when they started competing. High-level athletes who return to high-intensity training while breastfeeding may lose too much weight and they may need to compensate with increased consumption of energy-rich foods. Athletes often find it more comfortable to train after breastfeeding and need to be encouraged to use a snug sports bra that offers greater breast support without causing constriction. In addition, great care should be taken when selecting footwear and paths for walking or running, because the first activities that both athletes and active women return to are usually low-intensity walking and running.

Among the limitations of the study, athletes who failed to respond to the questionnaire or provided incomplete response have not been included in study. Also, only athletes who give birth have been included, athletes who left competitive sports after giving birth have not been included in the study and it has not been possible to investigate their motivation.

CONCLUSIONS

Knowledgeable pregnancy management requires care at every level and sports activities, whether by an athlete or a non-athlete, should be seen as a useful tool for safeguarding the health of the mother and newborn.

COMPLIANCE WITH ETHICAL STANDARDS

Authors contribution

C.Bi.: Conceptualization, writing – original draft. E.L.: Writing – original draft, writing – review & editing. A.D., L.B., A.C.: Investigation. G.T.: Writing – original draft. M.Z.: Project administration. C.Bo.: Data Curation, formal analysis. E.A.: Project administration. A.S.: Supervision.

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Study registration

N/A.

Disclosure of interests

DB, EL, AD, GT, CB, LB, AC and AS have no conflicting relationships with companies or manufacturers with regard to the results of the present study and the results do not constitute an endorsement by the American College of Sports Medicine. MZ and EA are Artsana Group employees.

Ethical approval

The study design was evaluated and approved by the Review Board of the Institution of Sports Medicine and Science.

Informed consent

Informed consent was obtained from all the research participants.

Data sharing

Data are available under reasonable request to the corresponding author.

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