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Poor placental traits reduce kid birth weight in young Saanen dams in the first parity

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Abstract: Placental characteristics are the most important indicators of fetal growth and development that influence kid vitality. The aim of this study was to examine the effect of maternal parity on placental characteristics and birth-related traits in Saanen goats. The experiments were conducted on 41 singleton-bearing Saanen does, ranging from 1 to 4 years of age and classified according to first, second, and third parities. Birth weight, placental weight, placental efficiency, and cotyledon density were influenced by parity ($P < 0.05$). First-parity does had kids with significantly ($P < 0.05$) lower birth and placental weights than does of other parities, while they had significantly higher ($P < 0.05$) placental efficiency and cotyledon density. First-parity does had fewer ($P < 0.05$) large and total cotyledons than third-parity does. Cotyledon dimensions varied among parities ($P < 0.05$), while average cotyledon surface area and cotyledon efficiency were the lowest in the first-parity does ($P < 0.05$). The results suggest that younger dams in the first parity may alter placental characteristics and fetal development, resulting in a reduced birth weight from singleton gestations.

Key words: Maternal age, parity, placental characteristics, kid birth weight, Saanen

1. Introduction

Saanen is a breed of goat with a high tolerance to different climatic conditions and is mostly raised for milk production in various regions of Turkey (1,2). Recently this breed has gained increasing importance in order to improve the milk yield of local breeds of Turkey via crossbreeding studies (3). However, the most important problem in crossbreeding studies is viability of offspring (4,5). Previous studies suggested that there are intrinsic factors affecting postnatal mortality of offspring, such as parturition-associated events (6), management-associated factors (5,7,8), breed, parity, birth weight (9), and maternal care (10).

Implantation between embryonic membranes and the uterine endometrium begins around days 14 to 15 in does and placentation begins around day 21 of gestation (11). Raised projections in the uterine endometrium are caruncles in ruminants (4,11). Consequently, the placentome consists of a fetal cotyledon created by the fusion of a vascular chorion and the vascular allantois and a maternal caruncle originating from the uterine wall (4). After implantation, the placenta is established and it reaches a maximum size and weight by day 90 of gestation; no change in tissue dry matter content occurs due to the expansion of fetal villi and their associated capillary network (11,12).

Placental characteristics are important indicators of the postnatal mortality of offspring in small ruminants (4). Mellor and Stafford (13) reported that the postnatal viability of newborns is associated with placental growth and development during gestation. The exchange capacity of caprine placenta between maternal and fetal systems depends on placental size and number of placentomes (4). Therefore size, which is related to the nutrient transfer capacity of the placenta, plays a pivotal role in determining the prenatal growth trajectory of the fetus and hence birth weight and postnatal viability (14).

Placental growth and development support fetal development during mid- to late gestation (12,14). Previous studies indicated that placental development during gestation is dominantly affected by maternal factors, especially nutrition levels (14–16). Moreover, many studies have demonstrated that there are significant relationships between placental weight (PW) and birth weight (BW) of the newborn (14,17,18). Kaulfuss et al. (19) suggest that multiple gestations affect PW and cotyledon surface area. Dwyer et al. (9) reported that parity affected BW and placental characteristics. Moreover, Wallace et al. (20) suggested that nutrient partitioning during gestation changes to promote the growth of the maternal body at the expense of the gradually increasing nutrient requirements of the gravid uterus and mammary gland in young,

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growing mothers. Thus, adolescent dams have an increased risk of a major restriction in placental mass, which leads to a significant decrease in BW and an increase in mortality rates of offspring until weaning. Additionally, multifetal gestation shares one placenta and decreases in placental angiogenesis and vascularity, which are associated with reduced uteroplacental blood flows as well as reduced placental and fetal growth (21). Thus, placental efficiency (PE) is not only reflected by PW or size, and whether or not there is a placental effect on growth and development of fetus from this BW and postnatal viability is unclear. Therefore, we hypothesized that younger dams in the first parity may alter placental development due to a large part of the nutrition intake being allocated to body mass growth, resulting in changes in placental characteristics and BW. Whether or not multiple gestations sharing one placenta has an effect on fetuses' development is not well understood. We chose does that give birth to singletons in the present study. The aim of the present study was to examine the effect of parity (1st, 2nd, and 3rd) on placental components related to birth traits in the Saanen goat.

2. Materials and methods

The study was conducted on 41 singleton-bearing Saanen does with different ages and parities in a private dairy farm in Samsun, Turkey (41°43′N, 35°82′E and 171 m above sea level) in the normal breeding season. The distribution of singleton kids with respect to different parities is presented in Table 1. All does were naturally impregnated using mixed multiple sires. Doe parity was classified as 1st, 2nd, and 3rd. First-parity does were all yearlings (n = 13), second-parity does were either 2 or 3 years old (n = 17), and third-parity does were either 3 or 4 years old (n = 11). All does were housed and cared for under the same conditions in the stockyard and were allowed to graze for 5 h daily during gestation. Experimental does were fed 250 g/doe/day of concentrate and 1 kg/doe/day of good quality alfalfa hay to meet their daily nutritional requirements during gestation.

BW and the sex of kids were recorded within 12 h after parturition. Each doe was left to deliver the placenta naturally and placentas were collected immediately after delivery; PW was measured and recorded after removing placental fluid. The total cotyledon numbers (TCN) and total cotyledon weights (TCW) of placental cotyledons dissected from the chorioallantois were also counted and determined. Cotyledon length (CL), depth (CDe), and width (CWi) were measured with a digital compass and 30 cotyledons of the same size were selected (small, <10 mm diameter; medium, 10–30 mm diameter; large, >30 mm diameter). Cotyledon density (CD) was calculated as the number of cotyledons per gram PW. Cotyledon efficiency (CE) was defined as the ratio of kid BW in grams to the total cotyledon surface area (TCSA). TCSA was calculated after the measurements of all the cotyledons in individual placenta as cm^2 with the following formula: radius squared of cotyledon $[((CWi + CL) / 4)^2] \times 3.14 (\pi) \times TCN$. PE was calculated as the ratio of kid BW to PW for each doe.

The effects of doe parity on kid BW, placental characteristics, and other variables were analyzed using a completely randomized design by the general linear model procedure of SPSS. The sex of kids was used as a cofactor in the model to adjust the BW and the placental characteristics. Significant differences between means were tested using Duncan's test and results were computed as mean ± SEM. Statistical significance was considered at $P < 0.05$ and $P < 0.01$. Poisson regression analysis was used to determine the effect of doe parity and kid sex on cotyledon number. Relationships between variable traits for discrete data were determined with Pearson correlation analysis at the 95% confidence interval.

Table 1. The distribution of singleton kids born from does with different parities.

Parity	Male	Female	Total
First	7	6	13
Second	8	9	17
Third	5	6	11

3. Results

In the present study, there were significant differences ($P < 0.05$) among does in the first, second, or third parity in terms of BW after kidding (Table 2). The BW of the does in the first parity were lower (32.8 ± 3.6 kg) than does in the second (41.7 ± 4.9 kg) and in the third parity (46.3 ± 5.3 kg).

Kid BW and some placental characteristics of the does in different parities are presented in Table 2. Kids born to first-parity does had significantly ($P < 0.05$) lower BWs than those born to does in the second and third parity. Similarly, the first-parity does had lower PWs ($P < 0.05$), but they had higher ($P < 0.05$) PE than does in the second and third parities. There were no significant differences among parities in terms of average cotyledon weight; however, TCW of first-parity does were lower ($P < 0.05$) than those of does in the second and third parities. Kid sex had no effect on BW, PW, TCW, and PE, but the average cotyledon weight of female kids were lower ($P < 0.05$) than those of male kids.

Size, number, and density of placental cotyledons of does in the different parities are present in Table 3. Small and medium cotyledon numbers were similar among does in the first, second, and third parities, but large cotyledons

Table 2. BW of kids and some placental characteristics of does in the different parities.

Parity	BWD (kg)	BW (g)	PW (g)	TCW (g)	ACW (g)	PE
First	32.8 ± 3.6^{b}	3136.5 ± 38.7^{c}	421.6 ± 24.5^{b}	160.71 ± 5.1^{b}	1.4 ± 0.1	7.8 ± 0.5^{a}
Second	41.7 ± 4.9^{a}	3665.9 ± 43.7^{b}	627.1 ± 24.4^{a}	205.22 ± 8.2^{a}	1.6 ± 0.1	6.0 ± 0.3^{b}
Third	46.3 ± 5.3^{a}	3848.6 ± 47.7^{a}	696.3 ± 39.0^{a}	230.1 ±13.5^{a}	1.7 ± 0.1	5.7 ± 0.3^{b}
Sig.	0.012	0.001	0.001	0.001	0.146	0.003
Kid sex						
Male	-	3574.8 ± 64.5	589.3 ± 34.5	205.0 ± 8.1	1.7 ± 0.1^{a}	6.5 ± 0.4
Female	-	3496.7 ± 83.1	563.4 ± 31.2	182.4 ± 10.0	1.4 ± 0.1^{b}	6.5 ± 0.3
Sig.	-	0.455	0.590	0.083	0.044	0.938

a, b, c Different superscript letters in the same column indicate significant difference (P < 0.05).
BWD = body weights of does, BW = birth weight, PW = placental weight, TCW = total cotyledon weight, ACW = average cotyledon weight, PE = placental efficiency.

Table 3. Size, number, and density of placental cotyledons of does in the different parities.

Parity	CNs	CNm	CNl	TCN	CD
First	11.9 ± 1.4	101.5 ± 5.1	6.1 ± 1.2^{b}	119.5 ± 5.4^{b}	0.3 ± 0.01^{a}
Second	11.8 ± 1.4	102.0 ± 4.0	13.6 ± 2.2^{a}	127.3 ± 4.6^{ab}	0.2 ± 0.01^{b}
Third	16.5 ± 2.6	105.6 ± 6.7	14.6 ± 3.0^{a}	136.6 ± 3.6^{a}	0.2 ± 0.01^{b}
Sig.	0.106	0.851	0.020	0.042	0.002
Kid sex					
Male	10.8 ± 1.1^{b}	102.6 ± 4.0	11.9 ± 2.1	125.5 ± 4.2	0.2 ± 0.01
Female	15.9 ± 1.6^{a}	102.6 ± 4.1	10.8 ± 1.6	129.3 ± 3.8	0.2 ± 0.01
Sig.	0.019	0.960	0.683	0.525	0.446

^{a,b} Different superscript letters in the same column indicate significant difference (P < 0.05).
CNs = cotyledon number small, CNm = cotyledon number medium, CNl = cotyledon number large, TCN = total cotyledon number, CD = cotyledon density.

and TCN of first-parity does were lower (P < 0.05) than those of third-parity does. CD of first-parity does was higher (P < 0.05) than those of does in the second and third parities. Kid sex did not affect the number of medium and large cotyledons, TCN, or CD; nevertheless, female kids had more (P < 0.05) small cotyledons than male kids.

Dimensions, surface area, and efficiency of placental cotyledons of does in the different parities are present in Table 4. CWi, CDe, and average cotyledon surface area in first-parity does were lower (P < 0.05) than in third-parity does. CE of does was lower in the first parity (P < 0.05) than those of does in the other parities. Kid sex had no effect on sizes, surface area, and efficiency of placental cotyledons.

Poisson regression analysis of parity and kid sex on the number of cotyledons are presented in Table 5. Poisson regression analysis, which is used generally for count data, was significant for parity. It also showed that the number of large cotyledon numbers was highest in the placentas of third-parity does because the regression coefficient (+0.945) was only positive for does with large numbers of large cotyledons. Moreover, kid sex had no effect on cotyledon numbers, except for small ones.

Pearson correlation coefficients of placental characteristics and birth-related factors are presented in Table 6. There were positive correlations between BW and PW (0.593; P < 0.01), TCN (0.370; P < 0.05), TCW (0.510; P < 0.01), CWi (0.388; P < 0.05), CL (0.386; P < 0.05), CDe (0.490; P < 0.01), average cotyledon surface area (0.352; P < 0.05), and TCSA (0.463; P < 0.01) for Saanen does in the different parities. In contrast, negative relationships were obtained between BW and CE (−0.356; P < 0.05), CD (−0.542; P < 0.01), and PE (PE) (−0.390; P < 0.05). Positive correlations between PW and the number of large

Table 4. Dimensions, surface area, and efficiency of placental cotyledons of does in different parities.

Parity	CWi (mm)	CL (mm)	CDe (mm)	ACSA (cm^2)	CE
First	18.4 ± 0.8[b]	26.0 ± 0.9	4.2 ± 0.1[b]	3.93 ± 0.30[b]	12.3 ± 0.9[b]
Second	21.9 ± 0.8b[ab]	29.3 ± 1.0	4.6 ± 0.1[ab]	5.35 ± 0.37[a]	19.7 ± 1.4[a]
Third	22.5 ± 1.0[a]	29.8 ± 1.3	4.9 ± 0.2[a]	5.57 ± 0.53[a]	21.3 ± 1.8[a]
Sig.	0.024	0.160	0.014	0.013	0.001
Kid sex					
Male	21.3 ± 0.7	29.0 ± 0.9	4.6 ± 0.1	5.07 ± 0.3	18.3 ± 1.3
Female	20.5 ± 0.9	28.3 ± 1.1	4.5 ± 0.2	4.80 ± 0.4	16.9 ± 1.5
Sig.	0.507	0.617	0.377	0.598	0.478

[a,b] Different superscript letters in the same column indicate significant difference (P < 0.05).
CWi = cotyledon width, CL = cotyledon length, CDe = cotyledon depth, ACSA = average cotyledon surface area, CE = cotyledon efficiency.

Table 5. Poisson regression analysis of the effect of parity and kid sex on number of cotyledons.

	Parity				Kid sex		
	First	Second	Third	P	Male	Female	P
TCN	$e^{4.917}$–0.113	$e^{4.917}$+0.070	$e^{4.917}$+0.183	0.001	$e^{4.862}$–0.030	$e^{4.862}$+0.030	0.227
CNs	$e^{2.801}$–0.322	$e^{2.801}$–0.334	$e^{2.801}$+0.656	0.002	$e^{2.766}$–0.391	$e^{2.766}$+0.391	<0.001
CNm	$e^{4.659}$–0.039	$e^{4.659}$–0.034	$e^{4.659}$+0.073	0.566	$e^{4.631}$+0.003	$e^{4.631}$–0.003	0.924
CNl	$e^{2.684}$–0.868	$e^{2.684}$–0.077	$e^{2.684}$+0.945	<0.001	$e^{2.379}$+0.099	$e^{2.379}$–0.099	0.276

TCN = total cotyledon number, CNs = cotyledon number small, CNm = cotyledon number medium, CNl = cotyledon number large.

cotyledons (0.650; P < 0.01), TCN (0.353; P < 0.05), TCW (0.801; P < 0.01), average cotyledon weight (0.395; P < 0.05), CWi (0.622; P < 0.01), CL (0.554; P < 0.01), CDe (0.495; P < 0.01), average cotyledon surface area (0.594; P < 0.01), and TCSA (0.678; P < 0.01) were calculated. On the other hand, there were negative correlations between PW and CE (–0.604; P < 0.01), CD (–0.848; P < 0.01), and PE (–0.905; P < 0.01). There was a significant correlation between PE and CD (0.710; P < 0.01), CE (0.614; P < 0.01), and CE and CD (0.369; P < 0.05). In first step of the analysis, all the variables were included in the model and stepwise procedure was applied. In the second step, BW and average cotyledon surface area were introduced and previous variables were excluded. Curve estimation was applied to calculate the effect of BW and average cotyledon surface area on CE. Linear, quadratic, and cubic effects of both explanatory variables were found to be statistically significant (P < 0.05). The regression model was built as a cubic form and the stepwise variable selection process was applied to the model. Two models were selected; the first model was chosen as the most appropriate for the estimation.

Y = CE; X1 = average cotyledon surface area; X2 = BW

$Y = -1.308 + 3.842 \times X1$ $R^2 = 0.973$, $P < 0.001$

$Y = -7.998 + 3.521 \times X1 + 0.006 \times (X2)^2$ $R^2 = 0.998$, $P < 0.001$

4. Discussion

The present study showed that age and maternal parity affected BW, PW, PE, TCN, TCW, CD, and CE in singleton-bearing yearling Saanen does. Kid sex influenced average cotyledon weight and the number of small cotyledon.

Ocak et al. (22) showed that parity did not have a significant effect on lamb BW in ewes from different breeds. Conversely, Dwyer et al. (9) reported that lamb BW increased with maternal parity and that younger ewes had lower BWs than older ewes. Similarly, in the present study, yearling first-parity does produced kids with lower BWs than mature goats in the second or third parity; increasing parity led to an increase in BW of the newborn. As a general fact, does may be used as stock breed once they reach 60%–70% of their adult weight. In the present study, although the yearling does had sufficient live weight for breeding (approximately 33 kg), some of their placental

Table 6. Pearson correlation coefficients of placental characteristics and birth-related factors.

Traits	PW	CNs	CNm	CNl	TCN	TCW	ACW	CWi	CL	CDe	ACSA	TCSA	CE	CD	PE
BW	0.593**	0.094	0.215	0.271	0.370*	0.510**	0.190	0.388*	0.386*	0.490**	0.352*	0.463**	–0.356*	–0.542**	–0.390**
PW		0.255	–0.037	0.650**	0.353*	0.801**	0.395**	0.622**	0.554**	0.495**	0.594**	0.678**	–0.604**	–0.848**	–0.905**
CNs			0.035	0.217	0.483**	0.288	–0.069	0.148	0.137	0.140	0.173	0.352*	–0.317*	0.051	–0.284
CNm				–0.440**	0.793**	–0.316*	–0.764**	–0.422**	–0.451**	–0.144	–0.468**	–0.111	–0.029	0.352*	–0.127
CNl					0.107	0.749**	0.512**	0.849**	0.843**	0.142	0.869**	0.839**	–0.743**	–0.553**	–0.538**
TCN						0.137	–0.540**	0.030	–0.005	–0.029	0.003	0.404**	–0.485**	0.108	–0.474**
TCW							0.727**	0.768**	0.726**	0.541**	0.770**	0.758**	–0.583**	–0.722**	–0.613**
ACW								0.600**	0.592**	0.442**	0.618**	0.346*	–0.121	–0.638**	–0.109
CWi									0.955**	0.178	0.983**	0.904**	–0.830**	–0.613**	–0.476**
CL										0.211	0.985**	0.896**	–0.793**	–0.550**	–0.378*
CDe											0.220	0.183	0.008	–0.512**	–0.342*
ACSA												0.911**	–0.801**	–0.576**	–0.437**
TCSA													–0.916**	–0.481**	–0.581**
CE														0.369*	0.614**
CD															0.710**

BW = birth weight, PW = placental weight, CNs = cotyledon number small, CNm = cotyledon number medium, CNl = cotyledon number large, TCN = total cotyledon number, TCW = total cotyledon weight, ACW = average cotyledon weight, CWi = cotyledon width, CL = cotyledon length, CDe = cotyledon depth, ACSA = average cotyledon surface area, TCSA = total cotyledon surface area, CE = cotyledon efficiency, CD = cotyledon density, PE = placental efficiency.
* $P < 0.05$, ** $P < 0.01$.

traits (PW, TCW, TCN, and CE) were lower and their offspring had lower BWs than offspring from the mature goats. First-parity yearling does had lower BWs, which might have caused a delay in fetoplacental development during gestation, leading to a lower BW in kids. The underlying mechanism of this result can be explained by the fact that when their BW is lower, younger dams utilize a high level of dietary nutrients to promote their own growth (20). Otherwise, they might have allocated more nutrients to fetoplacental growth and development. In other words, when the does are not at an optimal breeding BW, their priority is their own nutritional requirements rather than those of their fetus. For this reason, breeders should develop strategies fulfilling both maternal nutrient requirements and fetoplacental growth and development, especially for younger pregnant does.

The results of the present study demonstrated that PW, TCW, and numbers increased with maternal parity, while CD decreased. Placentas of younger first-parity does were lighter and contained fewer cotyledons, with lower total weights, than those of does in other parities, but CD was higher in these does. Similarly, Konyali et al. (23) indicated that first-parity does had lower PWs and higher CD, but total numbers of cotyledon per placenta were greater than in higher parity does, which is in contrast to our study. Ocak et al. (22) also showed that maternal parity influenced placental traits, and that ewes in the 1st to 3rd parities had lower PW, TCNs, and TCWs than ewes in greater parities, without affecting the CD. Dwyer et al. (9) also reported that PW and average cotyledon weight did not change with the number of cotyledons or increase with ewe age or parity. This is contrast to Ocak and Onder (24), who reported that PW was not influenced by parity, but that TCN, TCW, and CD were affected. Previous studies showed that low PW and reduced numbers of cotyledons were associated with growth deficiency of the fetus (9,25,26). Therefore, these differences in PW, cotyledon numbers, and TCW by parity suggest that first-parity yearlings carried lighter kids than mature goats in the second or third parities. The reason for this is unclear, but future experiments may clarify this with histological studies. On the other hand, the reduced numbers of the cotyledons obtained from yearling doe placenta may show evidence of decreased fetus growth compared to older does. Moreover, TCWs were lighter in yearling does, and this seems to be due to a decrease in the number of large cotyledons.

Previous studies reported that PE increased with parity in beef cattle and sheep (9,27). However, Konyali et al. (23) and Ocak et al. (22) showed that PE did not change with the parity of doe and ewe, respectively. Contrary to these studies, PE decreased with parity in the present study. The main reason for the decrease in PE may be the low ratio of PW to BW in yearling does. Although increasing maternal parity improved PW and kid BW, PE decreased with parity and the PE of yearling first-parity does was higher in the present study. Dwyer et al. (9) reported that younger primiparous dams produce smaller offspring than multiparas and the placenta characteristics and maternal weight gain during gestation vary. Younger primiparous females may partition nutrients less efficiently to the gravid uterus than multiparas, resulting in a reduced growth and development of the placenta (9,28). This may be another example of the reproductive immaturity of younger primiparous females. Many mammal uteri do not return to their original size after the first gestation and pregnancy; thus they may remain more vascularized than the uterus of dams that have never given birth (9). Therefore, increases in PW between primiparous and multiparous does may be due to the increased size and vascularization of uterus support to the placenta development. This information demonstrated that older or high-parity does may have more efficient placenta for transferring nutrients to the fetus than low-parity or younger does.

Previous studies indicate that PE and CD are inadequate parameters for determining the placenta's true efficacy in transferring nutrients to the fetus (9,22). However, Ocak et al. (4) suggested that determining cotyledon efficiency by measuring the cotyledon surface area is a far more conclusive and reliable measure of placenta functional ability. Moreover, placenta nutrient transfer capacity is related to the expanding size of the exchange surface areas (29). Although it is difficult to evaluate the area of placental exchange surface, the surface area of cotyledons per placenta is a powerful indicator of fetomaternal connection and improves the estimation of the efficiency in how the conceptus receives sufficient placental nutrition to reach parturition (4). In the present study, CE in younger, first-parity does was lower despite the fact that they had higher PE. These results suggest that younger does may have insufficient placental exchange and low kid BW is a strong indicator of this situation. This means that a measurement parameter solely based on PE and CD will give an inadequate exchange capacity of placenta. Therefore, CE is a far better indicator for the efficiency of the fetomaternal connection than PE.

Previous studies reported that there was no significant correlation between BW and PW in sheep (22) and goats (4). However, in the present study, the Pearson coefficient showed a significant positive correlation between BW and PW. Echternkamp (27), Dwyer et al. (9), and Konyali et al. (23) reported similar findings for beef cattle, sheep, and goats. The positive correlation between BW and cotyledon numbers, total weights, and dimensions obtained in the present study are in agreement with past studies in beef cattle and sheep (9,22,27). Positive correlations were observed in the present study between PW and cotyledonal traits and dimensions, but there was a negative correlation in placental computations (PE, CE, and CD), supporting the findings reported by Ocak and Onder (24) and Ocak et al. (4). Increased PW caused an increase in TCN, cotyledon weight, and kid BW.

In conclusion, the results of the present study imply that maternal parity and age influence placental development and the exchange capacity of placenta to fetus, which reflect variations in kid BW. Younger dams exhibit different placental morphology, which causes placental insufficiency. Low kid BW in first-parity dams may be due to the lower placental growth as a result of immature does. Hence, these results may have implications for developing feeding strategies that incorporate both maternal nutrient requirements and fetoplacental growth and development, especially for younger pregnant does, during gestation. Thus, it is evident that yearling does must be bred with the expectation that the kids may be somewhat smaller and need more attention. Further investigation is recommended to identify the relationship between placental traits and maternal parity or age for postnatal development and vitality of kids.

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