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7 Violence against women in the evolutionary context: is the gender system the source of dystocic  
8 labor in modern human?

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## 16 17 **Abstract**

18 Violence against women is one of the most widespread violations of human rights in our world today. The  
19 gender system, an institutionalized system producing different roles for women and men, could be the source of  
20 a system of oppression of women that generates gender-based violence. Cultural practice affected by the gender  
21 system, such as food sharing, may explain biological difference between men and women. According to the  
22 “Nutritional Constraints on Women’s Size Selection” (NCWS) hypothesis, body size difference between men  
23 and women could be explained by the women’s limitation to the food access throughout human evolution. This  
24 hypothesis is investigated in this paper, through new insights from primatology, evolutionary anthropology and  
25 auxology. Based on their analyses, we suggest that sexual dimorphism, where males are bigger than females, is a  
26 primate condition rather than the result of the inequality in the food access. NCWS hypothesis suggests that  
27 nutritional constraints result in a limitation of growth and produce small pelvis. This would explain why modern  
28 humans exhibit a high frequency of fetal-pelvic disproportion resulting in a high maternal mortality without  
29 medical assistance. But previous works show that the pelvic shape is adapted to the parturition in different  
30 ciconstances (small bodied women, reproductive age). For these reasons, we suggest that the emergence of the  
31 gender system is not related to the specific obstetrical conditions of modern humans. Other hypotheses such as  
32 the obstetric dilemma or the energetic for growth and gestation bring specific explanations to the human birth  
33 patterns.

34 Count 246/250

## 35 **Keywords**

36 Pelvis, shape, obstetrics, domestic violence, gender system, diet.

37



39

40 Main text:

41 1 Introduction

42 The gender system is an institutionalized system involving unequal social relations between male and  
43 female. As a multilevel system of difference, it is based on cultural beliefs and unequal distribution of resources  
44 (Ridgeway & Correll, 2004). The consequences of the emergence of this system on the sexual body size  
45 dimorphism are questioned in this article. Evolutionary pressures have shaped human bodies during complex  
46 processes implying cultural, environmental and biological changes. Among cultural changes, social systems  
47 including cooperative or competitive and violent behaviors are supposed to explain some of our anatomical  
48 patterns (Shea, 1985; Plavcan and van Schaik, 1997). Some authors hypothesize that the unequal distribution of  
49 food resources between males and females acts during human evolution and leads to the sexual dimorphism in  
50 body size seen in extant humans (Wolfe & Gray, 1982; Touraille, 2005). In this hypothesis called “Hypothesis of  
51 Nutritional Constraints on Women’s Size Selection” (NCWS) (Touraille, 2013) the emergence of the gender  
52 system at an early stage of human evolution would generate this unbalanced food distribution. The suggested  
53 biological consequences are : 1) a smaller stature for females, 2) a reduction of the size of their pelvises and 3)  
54 an increased risk of experiencing difficulties (dystocia) at birth. Such a scenario is intriguing since it combines  
55 different aspects of human biology; *e.g.* sexual dimorphism in body size, growth process, pelvic sexual  
56 dimorphism, obstetrics, with a behavior (food sharing practice) that could be highly variable today.

57 First, the aim of this work is to present this NCWS hypothesis in the large context of primates (sexual  
58 dimorphism, mating system), evolutionary perspectives (obstetric dilemma hypothesis, energetic for gestation  
59 and growth hypothesis) and health (birth dystocia) and social issues (violence against women). The first part of  
60 this review addresses the question of the origin of violence that could lead to the VAW today and the unequal  
61 distribution of food resources, the cornerstone of the NCWS hypothesis. According to this hypothesis, specific  
62 behavior resulting from the emergence of the gender system explains sexual body size dimorphism in human.  
63 This gender system implies complex relationships between males and females since it requires a system of “self-  
64 evidence”. Such a system is certainly absent in non-human primate and we expect to find highly variable sexual  
65 body size dimorphism among primates according to the NCWS. Therefore, the second part of this work lies on  
66 the sexual body size dimorphism in primates. Finally, the NCWS posits that sexual body size dimorphism is  
67 disadvantageous for females, leading to a high rate of mortality during the birthing process. In this work, we  
68 therefore aim to find if the sexual body size dimorphism generates difficulties during childbirth in modern  
69 humans.

70 2 The representativeness of violence in humans, and its consequences in sexual dimorphism

71 2-1 Human violences and the sharing of resources.

72 In 2014, the violence in all its forms (self-directed, interpersonal and collective) accounts for 2.5% of  
73 global mortality worldwide, and represents the cause of the death of more than 1.3 million people. WHO  
74 estimates that 475000 people were victims of homicide. Rate of homicide is not distributed equally between sex  
75 and age: most of the victims of homicide are male (four times the rate of homicide of female) and young people  
76 (the highest estimated rates of homicide are for the group age of 15-29 years) (WHO, 2014). However, providing  
77 a complete view of human violence is difficult given its multiple forms *i.e.* political violence (Zwi, 1982),  
78 intimate partner violence (García-Moreno et al., 2005), child maltreatment (Danese & Widom, 2020), *etc...* The  
79 presence of violence in human societies could be related to our primate inheritance. Among mammals, primates  
80 widely used violence in their social relationships to ensure the reproductive success (Muller et al., 2007), or  
81 maintain a well-defined hierarchies within the group (Flack & de Waal, 2004) despite the cost for the victim in  
82 term of increased glucocorticoid secretion (Muller et al., 2007). Today, different levels of violence exist among  
83 human societies. Surprisingly, western societies may exhibit particularly high level of interindividual violence, in  
84 comparison with hunter-gathered societies. As well, many human societies, particularly those with low  
85 distinction among individuals and low population density, such as the Aka peoples or the Ache of Paraguay,  
86 share resources (hunted or gathered foods) and are based on a collaborative system between individuals. In these  
87 societies, where leadership is rarely a matter of competition (Knauff, 1991), “sharing” is a social imperative that  
88 structures different aspects of the life in the group (Spikins, 2019), which generates peaceful relations between  
89 individuals.

90 In the evolutionary context, the consequences of cultural practices on biological or anatomical patterns  
91 cannot be investigated reliably, except if the body retains the mark of a specific human activity. Skeletal  
92 evidences suggest that different forms of violence exist in the past (Goetz, 2010; Tung, 2012). Violence could  
93 have been used to solve adaptive problems, thus explaining the distribution of polymorphic traits in modern  
94 human population. For example, an intriguing but highly speculative hypothesis suggests that the  
95 representativeness of left-handers in human population could be related to fighting advantages (Raymond *et al.*,  
96 1996). A potential cause of the emergence of the violence in human societies is the transition between “simple”  
97 hunter-gathering and agricultural/sedentary systems. While human societies, such as nomadic foraging or  
98 forager-horticulturalists societies, exhibit a less decentralized and a more egalitarian social organization,  
99 “complex” hunter-gathered, more specifically sedentary societies, would possess a system of rank distribution  
100 that could generate tensions among individuals. This condition of relaxed social tension in foraging societies is  
101 supposed to be a persistent condition throughout *Homo sapiens* evolution. This evolutionary scenario assumes  
102 that the trajectory of human violence throughout human evolution has a U-shaped, where the extremities of this  
103 trajectory are represented by the violent societies of non-human primates (which depicts the hypothetic societies  
104 at the first step of human evolution) and the sedentary, ranked human societies (a social organization that is  
105 supposed to appear after the neolithic transition) (Knauff, 1991).

106 NCWS hypothesis suggests the emergence of a complex social organization, where individuals are  
107 ranked according to their gender. Access to food is dependent of the status of the individual according to this  
108 rank. In addition, sharing practices are more frequent in peaceful societies where social organizations are more  
109 egalitarian. This would suggest that unequal distribution of resources due to an arbitrary status (e.g. gender),  
110 would appear or be emphasized at a late stage of human history, with the emergence of complex social  
111 organization. While violence in human societies does not seem to be exclusively the result of our primate  
112 condition, is male aggression against females a specific primate pattern?

## 113 2-2 Males aggression against females in primates and evolutionary perspectives

114 In humans, gender violence, also named Violence Against Women (VAW) is an important public health  
115 issue today. VAW is geographically widespread: in 48 population-based studies from around the world, between  
116 10% and 70% of women reported suffering from domestic violence during their lifetime (Heise *et al.*, 1999).  
117 According to WHO, the range of ever-partnered women who suffered physical violence by an intimate partner is  
118 from 13% in Japan city to 61% in Peru province, with most sites falling between 23% and 49% (García-Moreno  
119 *et al.*, 2005). Furthermore, VAW has various aspects: from the gender pay gap to the domestic violence, VAW is  
120 now largely recognized as part of a broad-scale system of domination that affects women as a class (Schechter,  
121 1982).

122 Estimating the relationships between males and females during human evolution is difficult and almost  
123 speculative. However, some interpretations of the male-female interaction have been proposed based on the  
124 observation of mating strategies in non-human primates, and several patterns of sexual dimorphism observed in  
125 extinct hominins. In non-human primates, mating strategies could be identified according to different levels of  
126 male-to-male competition. For example, gorillas or baboons exhibit high level of male-to-male competition  
127 (Baniel *et al.*, 2017; Wright *et al.*, 2019). In such mating system, primates are expected to show more male-to-  
128 female aggression than species living in monogamous groups because polygyny is often associated with much  
129 more intense male-to-male competition for mates (Smuts and Smuts, 1993). Moreover, species that shows high  
130 level of male-to-male competition exhibits high level of body size and canine sexual dimorphism. Among these  
131 dimorphic traits, canine crown height dimorphism is strongly correlated with estimates of intrasexual  
132 competition (Plavcan and van Schaik, 1997). When considering the dimorphism of *Australopithecus africanus*  
133 and *Australopithecus robustus*, the estimated mating system for these early hominins is characterized by low-  
134 intensity of male-male competition (McHenry, 1992; Plavcan and van Schaik, 1997). While some estimators,  
135 such as canine occlusal dimorphism, offer apparently little information about mating system, these results  
136 suggested that Australopithecines would have a mating system with low level of male-to-male competition, and  
137 they likely experienced low level of male-to-female aggression. This may indicate that the relationships between  
138 male and female were peaceful at the early stages of human evolution. However, in recent human history the  
139 preservation of the skeletal remains (which are almost complete in comparison with the state of preservation of  
140 hominin’s remains), and the archaeological evidences offer the opportunity to improve our understanding of the  
141 status of women in ancient societies. In contradiction with the early stages of human evolution, some evidences  
142 suggest that women were the victims of social oppression. For example, in the site of Conchopata (Peru), the

143 remains of an old woman are strongly associated with the scenario of a life history of a battered female in the  
144 seventh century AD (Tung, 2012). In other archeological sites, anthropologists found a significant proportion of  
145 women and children in a probable context of massacre (Armit, 2011) or evidences of maltreatment in captive  
146 women (Martin *et al.*, 2010).

147 Mating system seems to affect certain aspects of sexual dimorphism. But among the potential sources of  
148 sexual dimorphism, nutritional factors are rarely investigated (Touraille, 2013). NCWS posits that the inequal  
149 access to food is involved in the sexual body size dimorphism. This hypothesis is intriguing since the distribution  
150 of food between males and females seems to be highly variable today. What are the sociological evidences of the  
151 inequality of food distribution and their potential effects for sexual dimorphism?

152 2-3 The inequality of food distribution between males and females in an evolutionary context

153 The gender system is a social system that determinates the number of gender and the role of each gender  
154 (Nanda, 1998). The gender system rules many activities in human societies. According to Touraille (2008), this  
155 is a system of oppression combined with a “system of self-evidence”. For example, in this system, a question  
156 about the reason of the difference between male/female activities is followed by the stereotypical answer: “it has  
157 always been like that”. Among the activities strongly codified in human societies, food sharing and meal-time  
158 rituals are affected by the gender system. Many societies proceed to an order in the division of animal protein for  
159 which women are negatively discriminated. This is the case in the study of Atse and Adon (2015), where this  
160 unequal sharing in the rural population of Akyé is based on ideologies from food myths. For example, Akyé  
161 women are not allowed to eat doe since a traditional cure, made off byproduct of doe (*i.e.* kaolin), is used in case  
162 of infertility. In turn, the consumption of doe leads to the risk of female infertility in the Akyé belief (Atse and  
163 Adon, 2015). This example illustrates how magical thinkink contributes to the food sharing discrimination, with  
164 the system of self-evidence. Other examples of food sharing discrimination exist in the world. In rural population  
165 of Greece, when there is not enough meat or even tomatoes in the diet composition of a family, a woman usually  
166 leaves her portion for her husband or her son (Fournier *et al.* 2015). The gender system is supposed to  
167 unconsciously rule the process of food sharing. There is a large range of variability in the cultural food practices  
168 among human societies. These cultural food practices may have an impact on the growth process and ultimately  
169 on body size. For instance, Richards (1932) describes the inequality of the food distribution between males and  
170 females in a Bantu sample. In this study, the author shows that biological aspect of diet is closely related to  
171 sociological patterns: the family structure and the relationship between family members affect food practices. An  
172 inequality in meat or protein intake could occur in human societies. For the Hadza population, diet for male  
173 includes 39,6% of meat versus 1,2% for female (Marlowe, 2010). Dietary protein has long been known to  
174 increase growth and adult body size. For example, dietary protein increases circulating levels of growth factor  
175 such as the insulin-like growth factor-1 (IGF-1) (Schurch *et al.*, 1998). The inequality in the composition of diet  
176 explains, for some authors, the dimorphism in body size (Jolly, 1984; Touraille, 2005). It would explain the  
177 difference of 2,5 to 7 inch of body size between males and females. However, dietary protein is not the only  
178 factor that contributes to growth efficiency. Protein increases urinary calcium losses (Dawson-Hughes, 2003).  
179 Since the calcium losses have a negative impact on the bone mineral density, an adequate calcium intake may  
180 help promote a favorable effect of dietary protein on the bone mineral density (Meyer *et al.*, 1997; Dawson-  
181 Hughes, 2003) and the growth process.

182 Evolutionary sociologists hypothesize that the access for food would be reduced for female given the  
183 gender system oppression. Understanding VAW in an evolutionnary context was previously attempt in several  
184 reports (Wilson and Daly, 1993; Peters *et al.*, 2002; Campbell, 2012) For example, Wilson and Daly (1993)  
185 suggest that one goal of VAW is to deter female infidelity. These studies questioned the origin of VAW. Others  
186 hypotheses are related to the impact of VAW during evolution, and its consequence for the sexual dimorphism.  
187 Many authors underline the role of sexual dimorphism on the mating system: the competition between males for  
188 the reproductive success selects bigger males and increases intraspecific sexual dimorphism (Wolpoff, 1976;  
189 Plavcan and van Schaik, 1997). For Sentell (2015) the increase of sexual dimorphism during human evolution  
190 emphasizes the vulnerability of female to “male power”. For some authors, a distinction exists between sexual  
191 selection and natural selection. This distinction explains the promotion of an anatomical trait useful for  
192 reproduction (advantageous trait for sexual selection) but disadvantageous for the species (disadvantageous for  
193 natural selection). Among these anatomical traits, size of human males is supposed to have inflicted damage to  
194 female bodies. NCWS hypothesis suggested that males became bigger than females or females smaller than  
195 males, because of male-male competition. This competition selects males with aggressive behavior and inclines

196 to the restriction of food access for the females. This restriction in turn increases sexual dimorphism and female  
197 vulnerability. Moreover, the female pelvis and the female body size are supposed to change allometrically. Then  
198 the birth canal became less-adapted to the delivery of a normal sized neonate. This incompatibility in size  
199 between neonate and birth canal, also called “fetal-pelvic disproportion”, is suggested to have increased female  
200 mortality during human evolution.

201 NCWS hypothesis posits that inequality in food distribution emphasizes the difference in growth  
202 potential between male and female, leading over multiple generations to a stabilization of size difference  
203 between male and female (Touraille, 2013). The main consequence today is the inequality in the food access as  
204 reflected in sociological or ethnological evidences. Moreover, the decreasing size of the female pelvis, relative  
205 to the size of male, would generate more risk of fetal and maternal death due to the complexity of the birthing  
206 process, and the tight cephalopelvic fit. The main consequence is the high mortality due to cephalopelvic  
207 disproportion today. In the next part of this work, we will address two questions: 1) Is the difference in body size  
208 between male and female due to a difference in the growth process? 2) Does adaptive allometric solution protect  
209 the birth canal size in a small-bodied population?

### 210 3 Sexual dimorphism and bimaturism from the primate perspective

#### 211 3.1 Sexual dimorphism in primates

212 Sexual dimorphism in primates has been investigated with different variables or index. Height and  
213 weight are the mean variables because they are simple and reflected the overall size/volum of the body.  
214 Anatomical specificities, such as the presence of a tail, make several indexes (*e.g.* ratio of distance from the  
215 vertex to most distal part of the tail between males and females) irrelevant for the comparison of sexual  
216 dimorphism among primates. Wood and Chamberlain (1986) analyse the relationship between body size and  
217 pelvic dimorphism in several species of primates including modern man. In this study, femoral length is used as  
218 a proxy of body height, and a sexual dimorphism index is calculated (female femoral length/male femoral length  
219 X100). This index is always smaller than 100%, indicating that females are always smaller than males in these  
220 primates. But sexual dimorphism index could be calculated with different variables such as body weight or trunk  
221 length. The table 1 shows these sexual dimorphism indexes from different studies. In a study of the sexual  
222 dimorphism of the cercopithecines in northeast of Gabon, the sexual dimorphism index, based on the trunk  
223 length, is always smaller than 100% (Gautier-Hion, 1975). Hamada *et al.* (1996) found that the mean adult  
224 weight is 53,2 kg for males, and 42,7 kg for females in chimpanzees. These findings are close to those from the  
225 Yerkes chimpanzees (Gavan, 1971) and give a dimorphism index, based on body weight, of 80%. Among  
226 primates, male body size is greater than female body size. This rule seems to be common in this order.

227 Difference in size between male and female occurs during the growth process. In primates, difference in  
228 growth process between male and female explains the sexual dimorphism in adult body size. For example,  
229 Hamada *et al.* (1996) show that in chimpanzees, males have two peaks of velocity growth during the juvenile  
230 stage when females have only one peak. The marked difference is the magnitude of the peak velocity between  
231 males (5,91 kg/yr) and females (4,8 kg/yr). For Leigh and Shea (1995), sex difference in rate growth primarily  
232 account for dimorphism in chimpanzees. For Shea (1985), in common and pygmy chimpanzees, females are  
233 bigger than males at the dental stage 4 (c.a. 6 yr) for both cranial and postcranial dimensions. The female growth  
234 spurt occurs at the dental stage 4 in chimpanzees, and 3 in gorillas, and may be related to the development of the  
235 reproductive system (Harcourt *et al.* 1980). Finally, at the end of the growth process, the asymptotic body mass  
236 is greater in male compared to female in chimpanzees and gorillas. Two major differences could explain the  
237 sexual dimorphism in asymptotic body mass: a difference in the duration of the growth process (*e.g.* males have  
238 a prolonged growth period and reach a bigger size) or a difference in the growth rate (males grow faster than  
239 females in the same period of the growth process). This combination of differences in duration and rate is the  
240 major explanation of sex difference in asymptotic body size in primates (Leigh & Terranova, 1998).

#### 241 3.2 Mechanisms of sexual dimorphism humans and primates

242 In humans, difference in body size is already present at birth, where males are 90g heavier than females  
243 (Janssen *et al.*, 2007). Compared to non-human primates, humans show specific patterns of the growth process.  
244 They have a slow growth rate during the 4-8 years, corresponding to the childhood period: humans have a stage  
245 of infancy which is absent in others primates (Bogin, 1997). But humans and non-human primates share a  
246 common pattern which is the bimaturism. Bimaturism is the difference in the duration of the growth process

247 between male and female (Leigh & Terranova, 1998). The spurt in growth rate at adolescence begins earlier in  
248 females than in males. Indeed, at the beginning of adolescence, females are generally larger than males. At  
249 twelve years old, mean body weight of females is 37 kg (+/- 4kg) and males body weight is 35 kg (+/- 4kg)  
250 (Sempé et al., 1979). Fig. 1 shows the growth of body height in a sample of males and females. Data are from a  
251 French longitudinal cohort study based on 588 boys and girls from 1954-1955 to 1974-1975. Inclusion criteria  
252 were: absence of congenital abnormalities and a birthweight between 2.5 and 4.7 kg (Sempé et al., 1979). The  
253 fig.1 shows that males exhibit a peak of growth rate at twelve year-old while females start to decrease their  
254 growth rate until the asymptotic body size is reached, at *ca.* 15 years old. In consequence, the arrest of growth  
255 occurs earlier in females than in males which are still growing up after 15 years old. This illustrates the  
256 bimaturism and is mainly explains by different level of hormonal secretion throughout adolescence. In primate,  
257 the serum hormone level plays a crucial role in the growth process. In the chimpanzee male the concentration of  
258 testosterone before 6 years of age averages 13 ng/dl whereas this concentration increases up to 400 ng/dl during  
259 the puberty (Martin *et al.*, 1977). In human, the serum testosterone concentration averages 9 ng/dl before 12  
260 years and 340 ng/dl at 14 years (Winter, 1978). Testosterone increases muscles size and the proportion of type II  
261 fibers (Bhasin *et al.* 1996). While testosterone plays a major role in the growth process especially in male, it is  
262 well-known that females exhibit a close correlation between the menarcheal age and the asymptotic body size  
263 (Simmons & Greulich, 1943), suggesting a strong correlation between the reproductive capacity and skeletal  
264 maturation. Menarche is related to the maturation of the hypothalamus and the secretion of hormones such as  
265 the oestrogen. This hormone is involved in epiphyseal fusion and could play a key role in the regulation of  
266 growth (Simm *et al.*, 2008).

### 267 3.3 Factors against bimaturism in primates

268 Among primates, the level of sexual body size dimorphism could be different. This difference could be  
269 explained by factors acting against bimaturism. Seasonality and food access may contribute to the limitation of  
270 the duration of growth process. Indeed, seasonality may select animals that are able to reach a certain size and  
271 level of foraging competence before a stressful season. This ecological risk may select short period of growth.  
272 This potential risk could explain low level of bimaturism and low level of sexual body size dimorphism in  
273 lemurs (Leigh & Terranova, 1998). However, for the anthropoid primates, the exposition to the same risk  
274 (seasonality) would produce slow growth rate over prolonged period (Janson & van Schaik, 1993). Slowing  
275 growth rate would represent a strategy that alleviates the energetic demand during stressful period. Reproductive  
276 success could be another important factor that would reduce the prolonged growth period in male and thus  
277 bimaturism. Males that exhibit a longer period of maturation are at risk of missing reproductive seasons during  
278 early adulthood. This reason would be another explanation, with seasonality, to the low level of bimaturism in  
279 lemurs (Leigh & Terranova, 1998). In human, bimaturism also explains sexual body size dimorphism. The  
280 level of sexual dimorphism is moderate in comparison with other primates such as gorillas (Table 1). This  
281 moderate level of sexual dimorphism and bimaturism could correspond with the moderate amount of polygyny in  
282 our species (Weisfield & Berger, 1983). environmental factors would also influence the growth process, and a  
283 recent study found that immune function plays a crucial role on growth (Urlacher *et al.*, 2017).

284 NCWS hypothesis suggests that food deprivation explains the difference in body size between male and  
285 female. If this hypothesis is true, this nutritional factor would affect body size only if food limitation occurs  
286 during the growth process, not after when the adult size is reached. However, ethnological studies show that  
287 societies where inequalities in food distribution between male and female exist, girls and boys are considered  
288 with the same status (subadult) and are equal in regard to the food distribution (Marlowe, 2010; Atse & Adon,  
289 2015). In the primate context, asymptotic body size difference is mainly explained by bimaturism, a pattern of  
290 the growth process shared by anthropoid primates and humans. The limitation to the food access (seasonal stress)  
291 could potentially change pattern of growth process, but this would not change body size sexual dimorphism since  
292 primates, such as lemurs, could follow an alternative adaptation involving an increase of growth rate instead of  
293 a prolonged duration (Leigh & Terranova, 1998). In humans, the difference in growth process between males  
294 and females is mostly explained by hormonal differences rather than nutritional differences.

295 NCWS hypothesis assumes that body size difference between male and female has implications for  
296 obstetrics and prevents the ability to give birth successfully. Indeed, pelvic size is supposed to become smaller  
297 while the maternal stature decreases as if pelvic size was scaled to the body size of the mother (Touraille, 2008).  
298 A major consequence would be the high rate of cephalo-pelvic disproportion, approximately 8%, in humans  
299 (Maharaj, 2010). In this hypothesis, the role of the pelvic morphology is not considered. Is there an adaptation of



300 pelvic morphology for the birthing function in small-statured women? What are the different patterns of human  
301 birth, and how are they explained in an evolutionary perspective?

#### 302 4 Birth process in humans

##### 303 4.1 Human birth patterns

304 Human birth is supposed to be unique among primates in many aspects (Rosenberg & Trevathan, 2002).  
305 The uniqueness of human childbirth relies on its complexity (*i.e.* birth is a lengthy and painful event) and  
306 difficulty (*i.e.* birth could be dystocic). However, recent evidences suggest that some characteristics of the  
307 birthing process are comparable between human and non-human primates (Pan *et al.*, 2014; Kawada *et al.*,  
308 2020). NCWS hypothesis supports that the high rate of cephalo-pelvic disproportion, typical of humans, has a  
309 cultural explanation and could be due to food deprivation. However, several non-human primate species such as  
310 squirrel monkeys, exhibit a tight cephalopelvic fit and high neonatal mortality, from 13% to 35% (Coates *et al.*,  
311 1995). These would suggest that among primates, the high frequency of labor dystocia is not unique to humans.  
312 Kawada *et al.* (2020) found that rhesus macaques exhibit a tight cephalo-pelvic fit as humans do (Frémondrière *et al.*,  
313 2021). In our specie, what makes our birth special is the way the fetus negotiates the convoluted shape of the  
314 birth canal. The typical movement of the fetal head is called birth mechanism (Frémondrière *et al.*, 2017). This  
315 birth mechanism is explained by the shape of the birth canal. This canal is divided in three planes: the inlet,  
316 midplane and outlet. Inlet is the upper part of the canal, and is transversally elongated, while the midplane and  
317 outlet (lower part of the canal) are sagittally elongated. While the fetal head oriented itself in the most spacious  
318 space of each pelvic plane, a movement of rotation occurs as the presenting part passes from the inlet to the  
319 midplane. This movement requires the flexion of the head. Then, it follows a curved trajectory that passes in  
320 front of the ischial tuberosities. Therefore, human birth is said to be “ante-ischiatic” and it necessitates a birth  
321 attendant given the dominante occiput anterior position (Rosenberg & Trevathan, 2002). The human pattern of  
322 “obligate midwifery” or “obligate birth-attendant” would have deep consequences for the emergence of  
323 culturally specific rules and ritual behaviors associated with childbirth (Rosenberg & Trevathan, 2002).

##### 324 4.2 Birth process in extant human and sexual dimorphism

325 The shape of the birth canal plays a crucial role in the delivery outcomes. Birth is eutocic when birth  
326 canal shows a transversally large inlet (Fremondrière *et al.*, 2017), a sagittally (Harper *et al.*, 2013) and  
327 transversally elongated midplane, and a wide sub-pubic angle (Fremondrière *et al.*, 2017). These patterns are  
328 related to sexual dimorphism. For instance, female pelvises have wide sub-pubic angle and transversally large  
329 inlet compared to male pelvises (Cadwell and Moley, 1938). Among other dimorphic traits, the greater sciatic  
330 notch is more open in females than in males (Bruzek, 2002). This trait could be explained by the curved shape of  
331 the birth canal which contributes to the “ante-ischiatic” birth. These patterns of the birth canal (wide sub-pubic  
332 angle, transversally elongated inlet, wide greater sciatic notch) are related to the birth mechanism (rotational  
333 birth, ante-ischiatic birth). Even if the birth canal is larger than the true pelvis of males (Tague, 2000), its  
334 morphological patterns explain the complexity of the human birth. NCWS hypothesis posits that birth canal  
335 morphology is not adapted to the parturition (Touraille, 2005) but the patterns of sexual dimorphism contradict  
336 this suggestion. Moreover, a recent study shows evidences of developmental adaptation of the human female  
337 pelvis to the obstetric constraints (Huseynov *et al.*, 2016). According to these findings, female pelvis would  
338 exhibit developmental patterns resulting in the expansion of obstetric relevant dimensions during the age of  
339 maximum fertility (25-30 years old). However, the findings of a recent study show that pelvic shape variation is  
340 explained by neutral population history rather than obstetrical constraints (Betti & Manica, 2018). In this study,  
341 the geographical distance from Africa is used as a proxy of the neutral population history. When climate is  
342 considered as a factor of explanation of pelvic shape variability, its effect occurs differently on male and female:  
343 a significant correlation exists between climate and shape variability of male pelvises, but not female pelvises.  
344 For these authors, this difference is explained by the effect of obstetrical constraints (Betti & Manica, 2018).  
345 Given the role of the parturition in the shape of the birth canal, small-bodied women are supposed to have well-  
346 adapted pelvises since they are under intense influence of obstetrics selection.

##### 347 4.2 Body size dimorphism and pelvic dimorphism

348 According to the NCWS hypothesis, the consequence of the gender system is the reduction of the global  
349 size of the birth canal, which leads to the emergence of birth difficulties. For Touraille (2008), this oppression of  
350 males on females leads to the “pain and waste of life”. But in this hypothesis, adaption of small pelvises to the

351 obstetrical demand is not considered. NCWS hypothesis suggests that the major constraint of the reduction of the  
352 pelvis size is the body weight in the bipedal context (Touraille, 2008). Small-bodied women would be more  
353 lightweight and would exhibit a less reduced pelvic size. However, Fischer and Mitteroecker (2015) investigate  
354 this specific adaptation of small female pelvises. They found that small pelvic inlet is more rounded, which is  
355 more obstetrically efficient. For Kurki (2007), body size dimorphism and pelvic dimorphism are not related.  
356 Differences between short and tall females are not significant for the posterior spaces of the three pelvic planes.  
357 Moreover, small females have a longer sagittal outlet than tall females (Kurki, 2007, but see Kurki & Decrausaz  
358 2016). The adaptation of the inlet shape is crucial for the success of parturition since the inlet is a bony ring  
359 where the effect of pelvic relaxation is minimal (Frémondrière et al., 2021). Moreover, a sagittally elongated  
360 outlet is important during the expulsion stage since it facilitates the “ante-ischiatic” and “occiput anterior” birth.  
361 Birth canal of short female is therefore well-adapted to the parturition. The specific examination of the pelvic  
362 traits at the birth canal shows that the body size and birth canal size are not correlated (Kurki, 2007; Fischer and  
363 Mitteroecker, 2015). The decreasing size of female may be not correlated to obstetrical difficulties as suggested  
364 by the NCWS hypothesis and the pelvic shape of small women is also well-adapted to the parturition.

#### 365 4.3 The obstetric dilemma, an alternative explanation to the emergence of the food sharing

366 In the NCWS hypothesis, “food sharing” behavior plays a crucial role in the explanation of sexual body  
367 size dimorphism. An alternative hypothesis suggests that “food sharing” appears during human evolution though  
368 the emergence of secondary altriciality (Spikins, 2019). According to this, complex relationships and intensive  
369 social behavior appear during human evolution with the acquisition of a specific neuro-developmental phase in  
370 infant life. Such a complex relationships and intensive social behavior are in accordance with the “obligate  
371 midwifery” pattern which makes the birth process a social event (Rosenberg & Trevathan, 2002). Portmann  
372 (1941) suggested that human embryonic development lasts 21 months and is divided into two periods:  
373 intrauterine (9 months) and extrauterine (12 months). As a result, the human neonate retains fetal patterns of  
374 brain growth when delivered, and benefits of the life outside the mother to acquire important cognitive and  
375 behavioral functions (“extra uterine spring” hypothesis).

376 Fig. 2 shows the mean differences between the obstetric dilemma hypothesis (ODH) and the NCWS  
377 hypothesis. According to this hypothesis, Male-male competition selects males with aggressive behavior and this  
378 generates sexual inequality in the access to food (a primate initial condition), Inequality in the access to food is  
379 promoted through the emergence of the gender system. This difference in the access to food leads to the general  
380 reduction of the size of the birth canal. Such a reduction increases the cephalo-pelvic mismatch between the  
381 pelvis and the neonate, which leads to the increasing risk of fetal-pelvic disproportion and obstetrical difficulties  
382 (Maharaj, 2010). Moreover, the inequality in the access to food explains the dimorphism in body size between  
383 men and women. Alternatively, the obstetric dilemma hypothesis supposes that the acquisition of bipedal  
384 locomotion, and the increasing size of the neonatal head promote the emergence of a complex way to give birth  
385 (obstetric mechanism and difficulties during childbirth). Contrary to the NCWS hypothesis, ODH does not  
386 assume that locomotion reduces the size of the birth canal, but increases the complexity of the shape of the birth  
387 canal (this canal is curved in modern human but straight in non-human primate) which explains the birth  
388 complexity and difficulties today. Bipedalism and erected posture are supposed to deeply reshape the birth canal  
389 with the shortening of the distance between the sacro-iliac joint and acetabulum (Straus, 1929; Berge, 1984)  
390 while increasing size of the adult cranium during human evolution (*i.e.* encephalization process) is correlated  
391 with the increasing size of the neonate heads (DeSilva and Lesnik, 2008). The ODH assumes that secondary  
392 altriciality originates from these two opposing forces (encephalization vs bipedalism) (Washburn, 1960). An  
393 alternative hypothesis, the energetic for gestation and growth hypothesis (EGG hypothesis) assumes that the  
394 timing of parturition is constrained by the metabolic limitation of the mother instead of pelvic size (Dunsworth et  
395 al., 2012). EGG and ODH hypotheses are not mutually exclusive in this context. These hypotheses suggest a  
396 limitation to the increasing size of the neonate and the emergence of 2<sup>nd</sup> altriciality. Contrary to the NCWS  
397 hypothesis, we propose that the sexual dimorphism in body size is an initial primate condition, and is not  
398 generated by the inequality in the access to food. If food is inequally distributed between men and women, this  
399 cultural practice should originate from the complex social organizations that appears during mesolithic/neolithic  
400 transition (sedentary societies, emergence of leadership) (Knauff, 1991). The emergence of high social tensions  
401 during this transition would have generated inequalities between males and females in many aspects, including  
402 in food sharing.

403

404 5 Conclusion

405 Human sexual dimorphism must be considered in the primate context. Humans follow the general rule of the  
406 primate order where males are bigger than females. Human sexual dimorphism is not outside the primate range  
407 and some non-human primates show a bigger sexual dimorphism (e.g. *Gorilla*, *Cercopithecus*) than humans. The  
408 origin of sexual dimorphism lies on the sexual difference in the growth process. While food intake provides the  
409 energy to sustain growth, this process has a strong biological background. Its mechanism implies hormone level,  
410 sexual bimaturism and sexual differences already present at birth. Considering female food privation has the  
411 only source of explanation of sexual dimorphism seems unlikely. If female food privation is a part of the  
412 explanation of sexual dimorphism, it nonetheless has negligible consequences during the birth process, because  
413 small women show a specific adaptation of their birth canal shape to insure a successful birth. We suggest that  
414 inequity in food distribution between male and female is a recent phenomenon in human evolution, resulting  
415 from the emergence of large scaled-societies with high social tension. Complex birth process in extant humans  
416 may be explained by the tight fit between female pelvis and fetus size. The presence of this cephalo-pelvic tight  
417 fit would be more likely explained by mechanical (ODH) or energetic constraints (EGG), rather than the indirect  
418 consequence of the reduction of the female body size (NCWS).

419 Declaration

420 Competing Interests The authors declare no competing interests.

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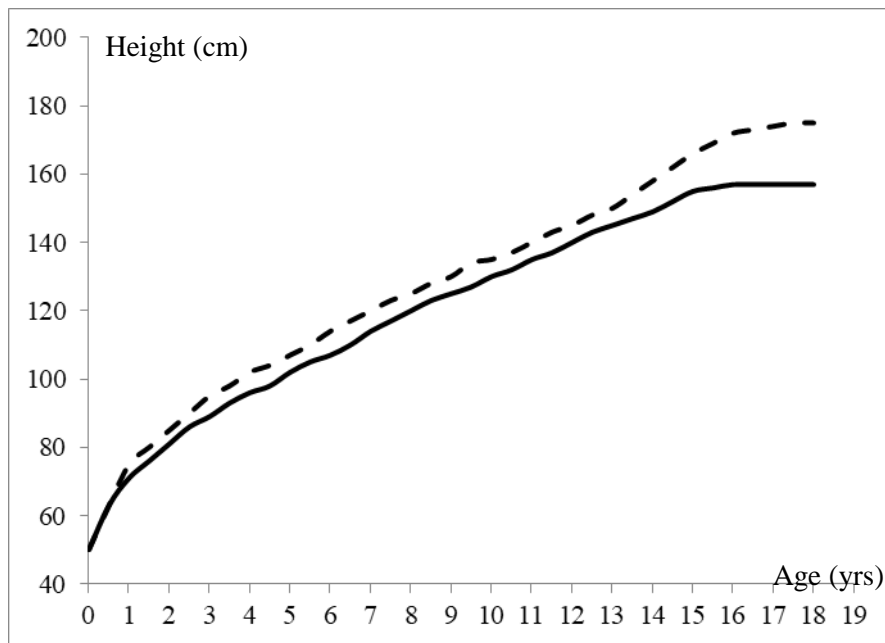
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596 Fig 1. Growth of body size in male and female

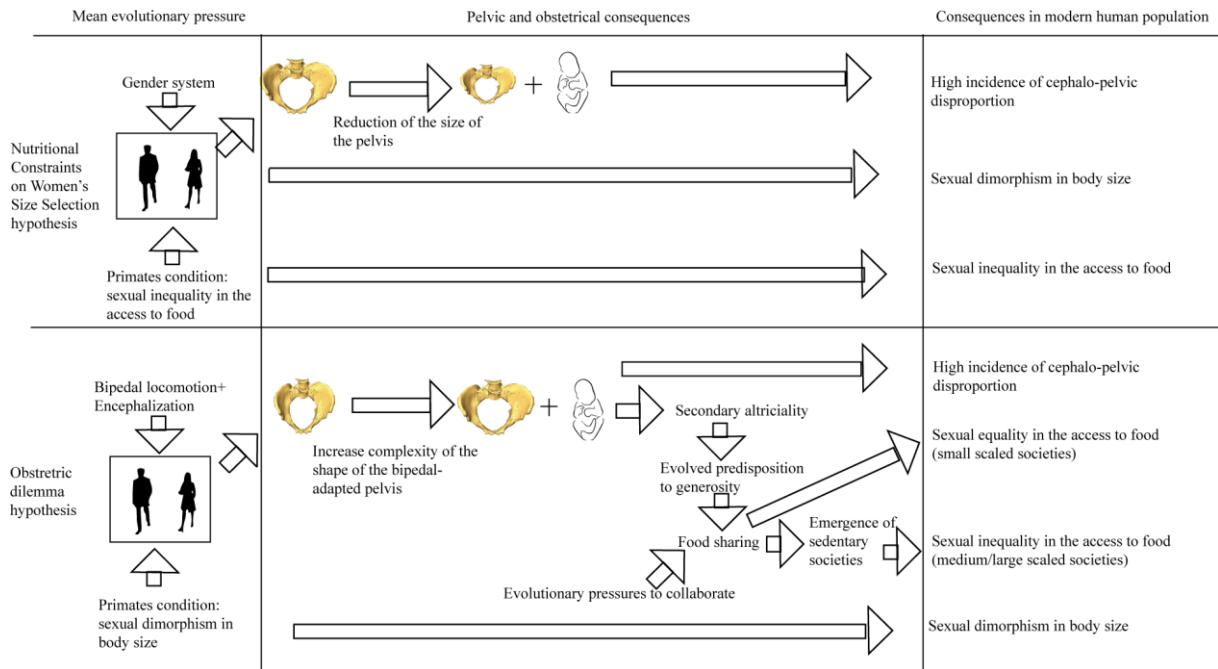


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598 Dotted line represents boy's growth, continued line represents girl's growth. Data are from a French cohort study  
599 based on 588 boys and girls borned between 1954-1955 (Sempé *et al.*, 1979).



600 Fig 2. Nutritional Constraints on Women's Size Selection Hypothesis versus Obstretic Dilemma Hypothesis for  
 601 the explanation of sexual body size dimorphism and birth patterns in extant humans.



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604 Table 1 : Body size dimorphism in primates

Primates species	Sexual dimorphism index	Variable	References
<i>Presbytis spp.</i>	95	femoral length	Wood and Chamberlain, 1986
<i>Cercopithecus spp.</i>	84	femoral length	Wood and Chamberlain, 1986
<i>Colobus spp.</i>	96	femoral length	Wood and Chamberlain, 1986
<i>Homo spp.</i>	92	femoral length	Wood and Chamberlain, 1986
<i>Pan spp.</i>	94	femoral length	Wood and Chamberlain, 1986
<i>Papio spp.</i>	88	femoral length	Wood and Chamberlain, 1986
<i>Gorilla spp.</i>	83	femoral length	Wood and Chamberlain, 1986
<i>Miopithecus talapoin</i>	90	trunk length	Gautier-Hion, 1975
<i>Cercopithecus cephus</i>	87	trunk length	Gautier-Hion, 1975
<i>Cercopithecus nictitans</i>	81	trunk length	Gautier-Hion, 1975
<i>Cercopithecus pogonias</i>	83	trunk length	Gautier-Hion, 1975
<i>Cercopithecus neglectus</i>	77	trunk length	Gautier-Hion, 1975
<i>Lophocebus albigena</i>	90	trunk length	Gautier-Hion, 1975
<i>Cercocebus galeritus</i>	79	trunk length	Gautier-Hion, 1975
<i>Pan troglodytes</i>	80	body weight	Hamada, 1996
<i>Pan troglodytes</i>	89	body weight	Gavan, 1953
<i>Pan troglodytes</i>	90	body weight	Smith <i>et al.</i> , 1975
<i>Pan troglodytes</i>	98	femoral length	Shea, 1981
<i>Gorilla gorilla</i>	83	femoral length	Shea, 1981

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