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Marital violence and fertility in a relatively egalitarian high-fertility population

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Ultimate and proximate explanations of men's physical intimate partner violence (IPV) against women have been proposed. An ultimate explanation posits that IPV is used to achieve a selfish fitness-relevant outcome, and predicts that IPV is associated with greater marital fertility. Proximate IPV explanations contain either complementary strategic components (for example, men's desire for partner control), non-strategic components (for example, men's self-regulatory failure), or both strategic and non-strategic components involving social learning. Consistent with an expectation from an ultimate IPV explanation, we find that IPV predicts greater marital fertility among Tsimané forager-horticulturalists of Bolivia ($n = 133$ marriages, 105 women). This result is robust to using between- versus within-subject comparisons, and considering secular changes, reverse causality, recall bias and other factors (for example, women's preference for high-status men who may be more aggressive than lower-status men). Consistent with a complementary expectation from a strategic proximate IPV explanation, greater IPV rate is associated with men's attitudes favouring intersexual control. Neither men's propensity for intrasexual physical aggression, nor men's or women's childhood exposure to family violence predict IPV rate. Our results suggest a psychological and behavioural mechanism through which men exert direct influence over marital fertility, which may manifest when spouses differ in preferred family sizes.

Intimate partner violence (IPV)—defined as any intended physical, sexual or psychological harm towards a current or former romantic partner[1]—is a ubiquitous global phenomenon, particularly against women[2,3], with adverse health and economic consequences for individuals, families and communities. Despite diverse intervention strategies to minimize incidence[4], the ubiquity and persistence of IPV is a conundrum for both policymakers and evolutionary scientists. In addition to acute trauma, health consequences for female IPV victims include chronic pain, gynaecological problems, unwanted pregnancy, foetal loss, post-traumatic stress disorder and depression[5,6]. Moreover, children of women abused during pregnancy experience greater risk of low birth weight[7], suggesting that children may be indirect victims of IPV. Regarding men's physical IPV against women—the focus of this paper—ultimate and proximate explanations have been proposed. An ultimate explanation posits that IPV or its threat is used by a man to achieve a selfish fitness-relevant outcome through manipulation of a woman's sexual or other behaviour in the short or long term[8,9]. Proximate IPV explanations are diverse: some contain complementary 'strategic' components related to a desire for partner control or bargaining power within a couple or society[10–13]; others contain non-strategic components related to men's self-regulatory failure, psychosocial stress or their interaction[14]; and others contain both strategic and non-strategic components involving social learning[15,16]. Our use of the term 'strategic' in this context does not presume or imply deliberate strategizing or awareness by the perpetrator of the ultimate function of IPV; instead, we use this term to refer to those IPV motivations that implicate a man's self-interest in a manner consistent with an ultimate (that is, fitness-enhancing) function, albeit at a different level of analysis. In contrast, non-strategic refers to those IPV motivations that are inconsistent with male fitness maximization.

This paper has two goals. First, we examine a fundamental prediction of an ultimate IPV explanation focusing on the fitness consequences of IPV in a high-fertility forager-horticultural population, the Tsimané of the Bolivian Amazon. Specifically, we test whether IPV is associated with greater marital fertility, using a between- and within-participant design and detailed retrospective survey data spanning 1,905 marital risk-years ($n = 133$ marriages of 105 women). Explanations of human sexual aggression in evolutionary psychology[8,17,18] posit that the risk of paternity uncertainty promotes men's jealousy, which in turn promotes a suite of men's controlling attitudes (for example, towards partner vigilance) and 'mate guarding' behaviours (for example, IPV), jointly serving to secure or protect exclusive sexual access to a mate and ensure that paternal investment is directed towards biological offspring[19–24]. Of course, men's coercive control need not be limited to preventing or punishing women's sexual infidelity; IPV may be used to influence behavioural outcomes in any domain, so that a wife is more likely to defer to her husband's immediate fitness-relevant goals, while setting a precedent for future deference.

A related literature in behavioural ecology and evolutionary biology focuses on sexual conflict (that is, conflict between the evolutionary interests of individuals of the two sexes) over mating and parental investment, given differing genetic interests of reproductive partners and asymmetries between sexes in the costs and benefits of reproduction[25,26]. Because males typically invest less than females in parental care and are susceptible to cuckoldry when pair-bonded, males are typically expected to have a higher optimum mating frequency than females for maximizing fitness. Conflict over the optimal mating rate can, under various circumstances, result in a male physically coercing a female to mate with him, leading some researchers to regard sexual coercion as a third form of sexual selection, distinct from intrasexual competition for mates and intersexual mate choice.

While mounting evidence across a wide range of species, including non-human primates, and across diverse mating systems, is consistent with a primary prediction of the 'sexual coercion hypothesis' (that male aggression towards females increases male fitness[27–32]),

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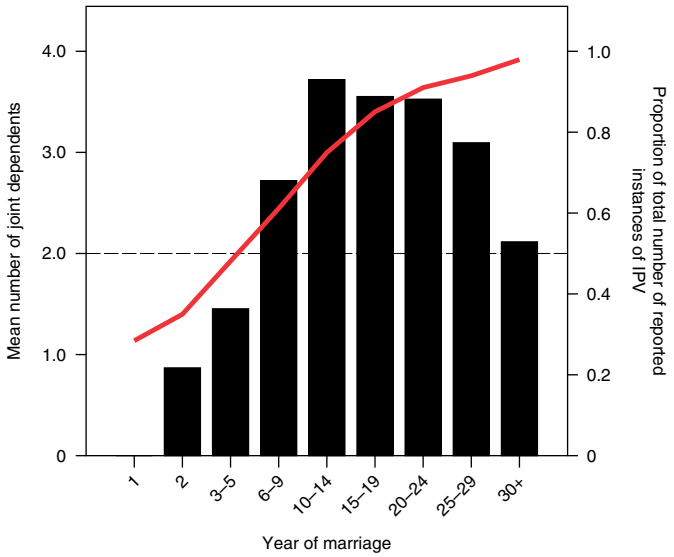

Fig. 1 | Cumulative relative frequency of IPV and number of joint dependents by year of marriage. The red line shows the frequency of IPV by year of marriage, while the black bars show the mean number of joint dependent offspring <10 years of age. Wives experience, on average, 50% of all IPV incidents by years 3–5 of marriage (indicated by horizontal dashed line), when a couple averages 1.5 joint dependents ($n = 89$ wives; omits 16 wives (15%) who never experienced any IPV in their lifetime).

the prediction that IPV increases marital fertility, which is central to an ultimate IPV explanation, has not yet been tested in a natural fertility population. Therefore, we tested for a positive association between IPV and marital fertility rate, both across women and within women across marriages. Testing within women permits assessment of whether women experiencing IPV have higher fertility than they themselves would have had if they had not experienced IPV. We also examine time dependence between IPV and marital fertility, and whether the results are artefacts of either secular changes, reverse causality, recall bias or other factors, such as women's preference for aggressive men or for high-status men who happen to be more aggressive than lower-status men.

There are several reasons why the Tsimané provide an interesting test of an ultimate IPV explanation. The Tsimané total fertility rate is nine births per woman, and birth control is rarely used[33], so covariation between IPV and fertility rate is easier to detect relative to industrialized populations, where sexual activity and reproduction are decoupled. Despite the generally collaborative nature of Tsimané marriages, interests of husbands and wives do not always coincide and there is substantial room for spousal conflicts of interest. Generally speaking, men experience lower costs of investment per child than women, and under certain socioecological conditions, this may result in larger ideal family sizes (IFSs) for men than women, as is observed among the Tsimané[33]. Interestingly, spousal disparity (husband–wife) in IFS is positively associated with 'excess fertility' (parity − IFS) for Tsimané women[33]. If husbands' coercion lowers wives' reproductive autonomy—as expected from an ultimate IPV explanation—husbands' larger IFS may lead to higher marital fertility than what their wives desire, and/or may encourage wives to adjust their IFS to accommodate their husbands' needs.

Despite room for spousal conflict and the use of IPV as a potentially effective means of sexual coercion, the Tsimané lack residential privacy due to large extended families living in closely spaced open houses, which increases the social costs to perpetrators who can restrict IPV occurrence. Nevertheless, a high lifetime IPV prevalence among Tsimané women (85%)[22] suggests that, even in a matrilocal population like the Tsimané, the presence of kin or other valued social partners is not sufficient to lower the IPV risk. This high lifetime IPV prevalence is puzzling because the Tsimané lack formal patriarchal institutions (for example, legal, political and economic), any recent history of large-scale (for example, intercommunity) violence and media exposure to violence.

A second goal of this paper is to identify, among the Tsimané, psychological and behavioural IPV determinants, and in so doing, consider the relevance of proximate IPV explanations that may include complementary strategic and non-strategic components. We test predictions of three proximate IPV explanations. First, we test whether a husband's attitudes towards controlling his wife are positively associated with his propensity to perpetrate IPV[9]. This association is consistent with an ultimate IPV explanation, and identifies a psychological mechanism promoting men's coercive behaviour that can increase the rate of copulation in marriage, minimize the risks of a wife's infidelity and increase men's marital fertility.

A second proximate IPV explanation we test emphasizes a causal role for men's aggressive personality[34,35], which predicts that a man's propensity to engage in intrasexual physical aggression is positively associated with his propensity to perpetrate IPV. In principle, this prediction can be consistent with an ultimate IPV explanation; for example, if aggressive men are more dominant (that is, better able to inflict costs on others), they may gain fitness advantages associated with such dominance[36]. However, much of the relevant literature posits that men's aggressive personality is indicative of broader self-regulatory failure (for example, a lack of dispositional self-control[34,35] or from male psychopathology[14]) that triggers IPV perpetration independently or in interaction with psychosocial stress (for example, related to absolute or relative poverty[37] or occupational stress[38]). In the current context, the Tsimané lack norms linking physical aggression to broader notions of 'manhood' as they pertain to interpersonal relations among men.

A third proximate IPV explanation we test emphasizes a causal role for socially learned attitudes of what constitutes 'appropriate' adult behaviour[15,16], which predicts that men's and women's childhood exposure to family violence is positively associated with men's propensity to perpetrate IPV. Childhood exposure to family violence can facilitate learning and internalizing a belief that IPV is justified for various reasons containing strategic and/or non-strategic components. Consider a household in which, first, a wife confronts her husband about his ongoing infidelities, resulting in his use of IPV to quell her protests, and shortly afterwards, the same husband, now inebriated and frustrated by his wife's complaints to him over his neglect of chores, unexpectedly uses force to abruptly end their dispute. In this example, co-resident children's social learning and internalization of expectations (for example, men's infidelity is common), attitudes (for example, men are justified in managing frustration with alcohol and hasty aggression) and behaviour (for example, men 'resolve' marital conflict through IPV) are temporally linked, and both strategic and non-strategic components may be modelled and imitated, facilitating intergenerational transmission of IPV. Interestingly, from an evolutionary perspective, one might also expect a positive association between childhood exposure to IPV and men's propensity to perpetrate IPV. This is because, despite direct costs to women of experiencing IPV, the potential fitness benefits that may accrue to abusive men can, in principle, generate indirect fitness benefits to women through their male children. This Fisherian notion suggests that women's preferences for abusive men can, in theory, originate regardless of social learning.

IPV was most common in the first year of marriage, before reproduction (Supplementary Fig. 1). During this first year, wives experienced, on average, 28% of all IPV incidents that eventually occurred in their marriages (Fig. 1). Among the 89 wives (85%) experiencing any IPV in their lifetime, the median number of total lifetime IPV incidents was 9 (mean = 21.0, s.d. = 27.8, min = 1, max = 135) and the median number of IPV incidents per year was

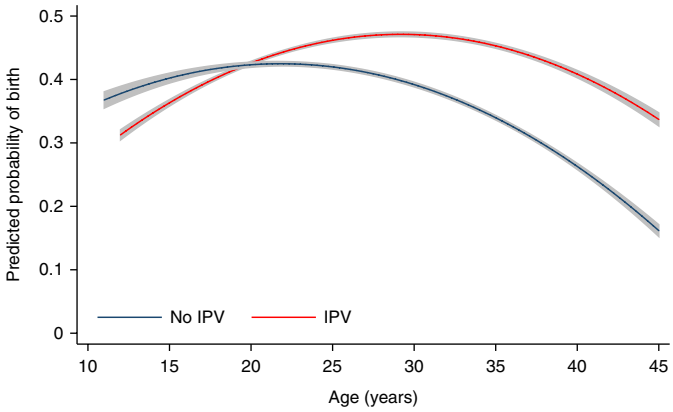

Fig. 2 | Predicted probability of birth within a year versus a wife's age and whether she reports IPV that year. Shaded areas represent 95% CIs (n = 1,905 marital years, 105 wives). Fitted values are derived from Supplementary Table 3 (model 2; holding controls at sample means).

0.8 (mean = 1.4, s.d. = 1.5, min = 0.03, max = 8.7). Compared with wives who never experienced any IPV in their lifetime, wives experiencing IPV were younger at the time of interview, had shorter interbirth intervals, and had more births for age and surviving offspring for age (Supplementary Table 1 and Supplementary Fig. 2). In contrast, there were no significant differences between wives who ever versus never experienced IPV in age at menarche, first marriage or first birth, prevalence of remarriage, anthropometric status, or indicators of modernization (that is, schooling and Spanish fluency). Wives experiencing any IPV in their lifetime were more likely than wives who never experienced IPV to have husbands with greater Spanish fluency (both absolutely and relative to the wife; Supplementary Table 2). In contrast, there were no significant differences between husbands whose wives ever versus never experienced IPV in age (either absolutely or relative to the wife), age at first marriage or first birth, prevalence of remarriage, anthropometric status (either absolutely or relative to the wife), or schooling.

Wives experiencing IPV in a given year showed increased odds of birth that year, controlling for confounders related to demographics, anthropometrics, modernization and village membership (adjusted odds ratio (OR) = 1.246, 95% confidence interval (CI): 1.021–1.520, P = 0.030; Supplementary Table 3, model 1). Inclusion of an IPV-by-wife's-age interaction term yielded a significant parameter estimate (P = 0.009; Supplementary Table 3, model 2), indicating an increasing difference in annual fertility between abused versus non-abused wives with age (Fig. 2).

The positive association between IPV and fertility could be an artefact of secular change, because younger women had both higher annual fertility and were more likely to experience IPV than older women when they were younger (Supplementary Fig. 3). To determine the potential artefactual effect of secular change, we added time period dummies (indicating terciles of years comprising the retrospective database) to model 2 in Supplementary Table 3 (see Supplementary Table 4, model 1), and found a nearly identical parameter estimate for the IPV-by-wife's-age interaction term (adjusted OR = 1.035, P = 0.003). This estimate increased if we omitted the most recent time period (2003–2012; Supplementary Table 4, model 2), and was nearly identical to that shown in Supplementary Table 4 (model 1) when we omitted the oldest time period (Supplementary Table 5), suggesting that the positive association between IPV and fertility is not an artefact of relatively recent increases in annual fertility and IPV exposure.

The positive association between IPV and fertility was also not an artefact of reverse causality, whereby having higher fertility increases the risk of IPV. There were no significant main effects of either annual fertility or the number of joint dependents (<10 years of age) on the probability of experiencing IPV per year after controlling for potential confounders (Supplementary Table 6, model 1; using the same controls as those shown in Supplementary Table 4), nor did these fertility measures interact to significantly predict IPV risk (Supplementary Table 6, model 2).

The positive association between IPV and fertility could also result from recall bias; for example, older women, having to recall older events than younger women, may be more likely to under (or over) report IPV, especially when less (or more) fertile. However, there was no evidence of systematic bias in reporting IPV across time periods (see Supplementary Fig. 3b): within a given age category and relative to women from more recent cohorts, older women reported both lower (<25 years old) and higher (35–39 years old) or comparable (25–34 and 40–45 years old) annual IPV rates. In addition, within each time period, annual IPV risk was negatively and significantly predicted by a wife's age, with similar declines in the slope (1953–1991: adjusted $OR_{wife's\ age}$ = 0.959 (95% CI: 0.922–0.998); 1992–2002: adjusted $OR_{wife's\ age}$ = 0.928 (95% CI: 0.875–0.985); 2003–2012: adjusted $OR_{wife's\ age}$ = 0.897 (95% CI: 0.858–0.938); generalized estimating equation (GEE) analysis controlling for village dummies). For the oldest cohort, an age-related decline in IPV risk was evident despite relatively minimal change in the fertility rate before the age of 35 years (Supplementary Fig. 3a). These results, coupled with the robustness checks mentioned above (that is, omitting the earliest and latest time periods from the analyses), suggest that the positive association between IPV and fertility is not an artefact of systematic recall bias.

The positive association between IPV and fertility could also result from women's preference for higher-status men who happen to be more physically aggressive than lower-status men. If this 'IPV-as-a-status-byproduct' interpretation were correct, we should find a positive association between IPV and fertility for higher- but not lower-status men. However, using two temporally stable correlates of adult male status—men's age at first marriage and Spanish fluency—and for each status subgroup (that is, higher and lower), analysing the effect of IPV on the probability of birth per year, we found that IPV positively and significantly predicts marital fertility for both higher- and lower-status men (using men's age at first marriage, the IPV-by-wife's-age interaction OR (95% CI) for men marrying earlier (below median) versus later (all others) = 1.056 (1.021–1.092) versus 1.030 (1.001–1.059), using the same controls as those shown in Supplementary Table 4; using men's Spanish fluency, the IPV-by-wife's-age interaction OR (95% CI) for fluent versus non-fluent men = 1.116 (1.023–1.218) versus 1.030 (1.001–1.060)). In addition, neither men's age at first marriage nor Spanish fluency was associated with men's attitudes regarding intrasexual physical aggression or actual physical aggression towards other men in the past year, indicating a decoupling of male status and intrasexual aggression that is not consistent with the IPV-as-a-status-byproduct interpretation.

Leveraging variation in fertility and IPV rates within women across marriages (n = 26 wives who remarried), we tested whether any IPV experience with each husband was associated with greater annual fertility with that husband (mean years married to first husband = 5.6, range: 1–28; mean years married to second husband = 13.6, range: 1–26). Wives experiencing any IPV with a first husband, but not a second, showed greater annual fertility with the first (0.375 versus 0.121, respectively), although a small sample size (n = 2 wives) precluded a formal test of this difference (Fig. 3). Wives experiencing any IPV with a second husband, but not a first, showed greater annual fertility with the second (0.426 (bootstrapped 95% CI: 0.323–0.540) versus 0.164 (bootstrapped 95% CI: 0.036–0.322)). This fertility increase with the second husband approached significance (related-samples Wilcoxon signed rank P = 0.063) despite a small sample size (n = 7 wives; mean years between the start of each

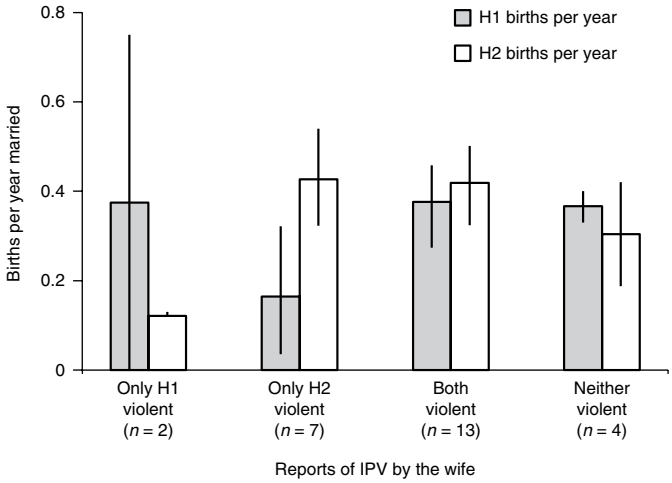

Fig. 3 | Annual fertility within marriage for the 26 wives who remarried by whether a wife experienced IPV with each husband (H). Error bars show bootstrapped 95% CIs. All but two wives remarried once; to minimize potential recall bias, we analysed the two most recent marriages for the two wives who remarried twice. A wife's mean ± s.d. age at remarriage was 24.3 ± 8.0.

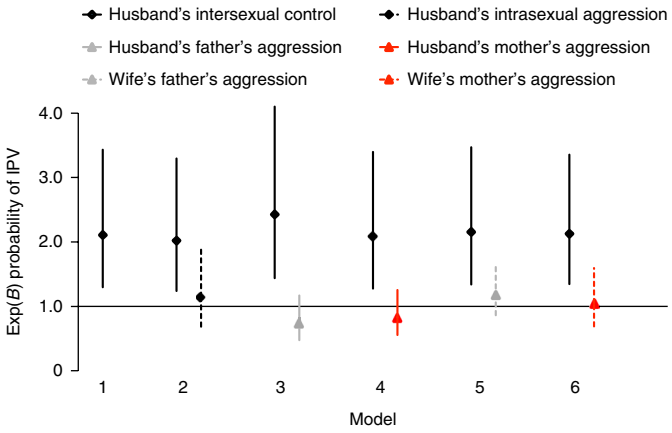

Fig. 4 | Effects of a husband's attitudes regarding intersexual control, intrasexual physical aggression, and childhood exposure to family violence (husband's and wife's) on the probability of IPV. The effect of a husband's attitudes regarding intersexual control on the probability of a wife reporting IPV in a year is shown in model 1. Model 2 shows this effect combined with intrasexual physical aggression. Models 3–6 show this effect combined with the husband's and wife's childhood exposure to paternal and maternal violence ($n = 909$ marital years, 49 wives; parameter estimates and 95% CIs are shown in Supplementary Table 7).

marriage = 2.7; range: 1–5). We found no significant differences across marriages in the rates of IPV or fertility versus whether a first marriage dissolved because of divorce or a husband's death.

To consider the relevance of proximate IPV explanations, we tested whether IPV was predicted by: (1) a husband's attitudes regarding intersexual control; (2) a husband's attitudes regarding intrasexual physical aggression (reflecting actual aggression towards other men; see Methods); and (3) paternal and (4) maternal physical aggression experienced or witnessed by husbands and wives during childhood. Controlling for predictors ($P < 0.1$) shown in Supplementary Table 4, the annual IPV risk was positively predicted by a husband's attitudes regarding intersexual control (adjusted OR = 2.108, $P = 0.003$; Supplementary Table 7, model 1), but not by a husband's attitudes regarding intrasexual physical aggression (adjusted OR = 1.147, $P = 0.602$; Supplementary Table 7, model 2), nor by a husband's paternal (adjusted OR = 0.747, $P = 0.204$; Supplementary Table 7, model 3) or maternal (adjusted OR = 0.834, $P = 0.385$; Supplementary Table 7, model 4) aggression during childhood, nor by a wife's paternal (adjusted OR = 1.183, $P = 0.298$; Supplementary Table 7, model 5) or maternal (adjusted OR = 1.049, $P = 0.824$; Supplementary Table 7, model 6) aggression during childhood (Fig. 4). Men's attitudes regarding intersexual control were positively associated with men's paternal aggression during childhood (Pearson's coefficient of correlation, $r = 0.403$, $P \leq 0.01$) and with men's attitudes regarding intrasexual physical aggression (Pearson's $r = 0.432$, $P \leq 0.01$) (Supplementary Table 13), suggesting that proximate IPV motivations may be linked. However, in models omitting a husband's attitudes regarding intersexual control, annual IPV risk was not predicted by a husband's attitudes regarding intrasexual physical aggression, or by a husband's or wife's paternal or maternal aggression during childhood.

We tested for other potential confounders related to demographics (that is, spousal age difference and previous marriage), anthropometrics (that is, height or weight (wife's, husband's or spousal differences)) and modernization (that is, schooling (wife's, husband's or spousal differences)), but none significantly predicted IPV risk.

We examined the fertility consequences of IPV, and behavioural and psychological IPV determinants, in a high-fertility population of Bolivian forager-horticulturalists to test predictions of ultimate and proximate IPV explanations. Consistent with a fundamental expectation from an ultimate IPV explanation, we found that IPV predicted greater marital fertility; consistent with a complementary expectation from a strategic proximate IPV explanation, a greater IPV rate was associated with men's attitudes favouring intersexual control. These results highlight a prominent sexual conflict even within the context of monogamous marriage in a population lacking formal patriarchal institutions and other widespread practices that limit women's reproductive autonomy (for example, female genital mutilation and marital restrictions). Sex-specific benefits and costs of reproduction (for example, maternal depletion) and differing genetic interests of reproductive partners are expected to generate sex differences in optimal values of fitness-relevant traits (that is, 'sexual conflict traits'[25,39]). This may include family size preferences, with men, under certain socioecological conditions (the Tsimané included), favouring larger families than women, partly due to men's reduced physiological and opportunity costs of birth[33]. Overt behavioural conflict between reproductive partners is expected if optimal outcomes for each partner cannot be achieved simultaneously[39]. Our results suggest a psychological and behavioural mechanism through which men exert direct influence over marital fertility, as men's desire for partner control and associated IPV may increase the rate of in-pair copulation (that is, direct coercion[27]). These and other coercive tactics, for example, intimidation through verbal aggression, facilitated by sexual dimorphism in strength, can serve to increase men's mating effort in the short or long term, both within and outside of marriage[22,40]. It may also be in a wife's interests to acquiesce to mating because the direct costs of resistance exceed the costs of allowing mating. In general, this interpretation is not inconsistent with—and may actually complement—one emphasizing conformity to and internalization of local gender norms that promote a husband's dominance over a wife (for example, regarding wifely obedience and 'appropriate' consequences for disobedience), even in a population lacking formal patriarchal institutions. While specific pathways linking desired spousal control and reproductive effort require further exploration, a mediation analysis indicates that Tsimané men's controlling attitudes do not predict wives' fertility independent of IPV, nor do they diminish the positive association between IPV and fertility.

A prediction of a proximate IPV explanation emphasizing a causal role for men's aggressive personality is that IPV perpetration positively co-varies with men's propensity to engage in intrasexual physical aggression[34,41]. Using data on men's attitudes regarding intrasexual aggression—itself predictive of actual aggression towards other men in the past year (see Methods)—we found that neither attitudinal nor behavioural (past year) measures of intrasexual aggressive tendencies predicted IPV perpetration, indicating a decoupling of men's aggression towards wives versus other men. It is thus unlikely that the positive association between IPV and fertility reflects women's preference for aggressive men, or that IPV is a byproduct of intrasexual competition involving aggression. Our previous Tsimané research[22,40] indicates that men's jealousy over women's infidelity does not precipitate most instances of verbal or physical aggression in marriage. Instead, based on couple-level data on marital arguments and IPV, our previous research indicates that it is Tsimané men's infidelity (perceived or real), not women's, that precipitates most instances of verbal conflict in marriage and wife abuse. Rather than resulting primarily from men's attempts to limit women's access to other mating partners (that is, indirect coercion[27]), Tsimané IPV may result from men's attempts to 'resolve' sexual conflict over preferred family size through direct coercion, although both strategies may co-occur. Future research, using couple-level data, that focuses on the temporal sequence of marital conflict will contribute to an understanding of couple-level contextual dynamics, including which partner initiates conflict, and broader escalation and conciliatory processes.

IPV tends to be more frequent and severe in lower socioeconomic-status subgroups[37], but IPV is not restricted to lower-status men. Even among the Tsimané, who, compared with other populations in the IPV literature, show limited variance in men's resource holdings, it is possible that, instead of reflecting a sexual coercion strategy, the positive association between IPV and fertility could instead reflect women's preference for high-status men who are also more aggressive than lower-status men. Our previous research has shown that abusive Tsimané husbands are more likely to engage in extramarital affairs[22,40], and while we have interpreted this as reflecting a strategic response (that is, men use IPV in part to control women's responses to men's diversion of household resources), an alternative interpretation is that abusers (versus non-abusers) can 'afford' extramarital affairs because of their greater resource-holding potential, which is desired by women. However, contrary to this alternative IPV-as-a-status-byproduct interpretation, we find that IPV predicts higher marital fertility for both higher- and lower-status men, and that men's status is uncorrelated with men's attitudinal or behavioural measures of intrasexual physical aggression. Moreover, men's status is not significantly associated with men's attitudes favouring intersexual control, contrary to the expectation that feelings of 'sexual proprietariness'[9] are stronger in lower-status men because of their elevated risk of losing a wife. Together, these findings indicate that Tsimané men across the status continuum strategically use IPV to achieve higher marital fertility, although it is noteworthy that the IPV-by-wife's-age interaction effect is stronger among higher- versus lower-status men. IPV may be a more effective strategy for high-status men because they incur fewer social costs of IPV (for example, retaliation from a wife's kin). Generally speaking, our findings do not directly support a prediction from a proximate IPV explanation that stress related to low status increases IPV risk, either independently or in interaction with men's aggressive personality.

A proximate IPV explanation involving social learning posits that children learn how to behave by experiencing how others treat them and by observing how their parents treat each other. Social learning (for example, of expectations, attitudes or behaviour) can provide a mechanism by which IPV is viewed as an appropriate response when sexual or other conflicts emerge. Yet, we find no support for a prediction of this social learning explanation: childhood exposure to family violence does not predict the risk of either perpetrating or experiencing IPV. This null finding holds if we use composite measures of physical aggression that incorporate overall paternal and maternal aggression (that is, towards a spouse, ego and ego's siblings; see Supplementary Table 7, models 3–6), and if we utilize specific measures of dyadic paternal aggression towards ego or a spouse. While the intergenerational transmission of IPV is one of the best-studied IPV explanations[16], it remains challenging to identify particular traits being modelled and imitated (for example, expectations about a partner's marital commitment, attitudes towards resolving conflicts peacefully, alcoholism) and address their inter-relationships in a comprehensive way that explains why only certain traits are transmitted and reliably associated with IPV. In principle, social learning of both strategic and non-strategic IPV motivations can occur. The learning of strategic motivation can occur through positive reinforcement of aggression, although the Tsimané lack norms linking aggression and masculinity, or norms justifying physical force to resolve conflicts among men. Failure to learn how to manage marital conflict appropriately might foster non-strategic IPV motivations. Nevertheless, in small-scale societies like the Tsimané, IPV perpetrators face substantial costs that should limit even greater IPV occurrence, including reputational damage and social sanctions, injury if IPV provokes retaliation by the wife and/or her kin, divorce and loss of future reproductive opportunities with a wife, and marital strife, which could lead wives to withdraw and/or reduce work effort as a means of protest[22].

Important study limitations should be considered. First, we focused only on physical IPV against wives; thus, we probably underestimate IPV prevalence. Second, social desirability bias often leads to IPV under-reporting, yet the Tsimané report a high lifetime and annual IPV prevalence, and couple-level data reveal substantial spousal consistency in reporting IPV (see Methods). For these reasons—together with a retrospective interview design, which we believe minimized study intrusiveness (since IPV is most common early in marriage and women's mean marital duration at the time of interview was 14.3 years)—we have no reason to suspect that potential reticence or deceit in our interview data produced the observed empirical associations reported here. Third, our retrospective study design lends itself to recall bias, although we found no empirical support that recall bias influenced the results. Fourth, we lack data on women's attitudes towards men's desires for intersexual control and men's use of aggression (intra- and intersexual), which are useful for further interrogating social learning and other proximate IPV explanations. Furthermore, we assessed attitudinal constructs with relatively simple measures that may not accurately represent the complexity of these constructs. We also lack data on men's and women's fertility desires (for example, IFS), which are useful for understanding the nature of spousal bargaining when conflicts emerge over family planning. Unfortunately, we do not have data on women's counter-strategies to minimize IPV risk; sexual conflict models propose an evolutionary arms race, whereby the costs to one sex from the other's behaviour create strong selective pressure for adaptive responses[42]. Given the emphasis of sexual conflict theory[39,43] on the dynamic, bidirectional nature of sex differences in optimal values of many fitness-relevant traits (for example, whether to mate, when, how often, how long for and how exclusively), it is misleading to perceive sexually coercive behaviour as the result of particular traits of particular men, rather than as a conditional response of men to women's behaviour that takes into account the costs and benefits of alternatives for both sexes[44]. It is also potentially misleading to only consider men's use of IPV, without considering couple-level contextual dynamics, including marital disputes and women's use of IPV. Finally, the sample size for our within-individual analysis was small, but we found similar results

for within- and between-individual analyses, supporting ultimate and strategic proximate IPV explanations.

To conclude, effectively minimizing the deleterious impacts of IPV for individuals, families and communities requires an accurate understanding of the factors causing IPV. A general theory—spanning proximate and ultimate levels of analysis—that explains why men engage in IPV, and that predicts the conditions under which IPV is more likely to occur, would be useful in the design of public health interventions to lower the IPV incidence and mitigate its deleterious effects. An implication of this study, for research and intervention design in public health, is that the conditions that increase spousal conflict over women's reproductive autonomy should be the target of explanatory models and attempts to lower the IPV incidence.

Methods

The Tsimané are semi-sedentary forager-horticulturalists living along the Maniqui River and surrounding areas in the Beni Department of Bolivia. Adults typically choose their own spouses, but kin may also facilitate marriages[45]. There are no formal marriage ceremonies and a couple is considered married when they sleep together in the same house. Post-marital residence rules are flexible but emphasize matrilocality early in marriage. Cross-cousin marriage is common and there are no formal marital restrictions. Birth control—mostly in the form of Depo-Provera—is only recently available from a few health workers and in pharmacies in town, yet <5% of reproductive-age women report usage[46]; other forms of modern birth control are almost never used. Low birth control usage is largely due to a combination of lack of knowledge about its use, cost and cultural valuation of large family size.

J.S. obtained University of New Mexico Institutional Review Board approval and informed verbal consent from the Tsimané government, village leaders and participants before conducting the study. IPV data were collected by J.S. and a trained male Tsimané research assistant in five villages (two downriver Maniqui villages (in 2007); one near a road (2010); and two upriver of Maniqui (2011)) varying in proximity to the market town of San Borja. Participants from each village were familiar with J.S. because he resided there for several weeks or months before collecting the IPV data. JS's Tsimané research assistant was not a resident of any sampled village, was not particularly well-known to participants, had previous experience conducting sensitive interviews (for example, on conflict with non-kin) as part of the Tsimané Health and Life History Project (THLHP) and was trained by J.S. in scientific research ethics. Women were queried about IPV as part of a broader interview on kin cooperation and conflict, in which women's current husbands also participated. Interviews were translated into Tsimané from Spanish, then back-translated into Spanish from Tsimané with assistance from two bilingual Tsimané research assistants who were part of the THLHP but otherwise unaffiliated with this study. Translation inconsistencies were resolved by J.S. and the three Tsimané research assistants, and the interview was piloted for three months in one village in 2007 as additional refinements were made by J.S. and his research assistant. Interviews were conducted privately in the field house of J.S. to ensure confidentiality, and in the Tsimané language to increase participants' comfort levels. To ensure participant safety and confidentiality, only one eligible woman was randomly selected per household for interview. To further ensure confidentiality, and given the lack of local violence-reporting laws, we did not report any violent incidents. Participant compensation included desirable store-bought items, such as soap for washing clothes, sugar, cooking oil, fishhooks, yarn for weaving, or rifle bullets or shotgun shells for hunting.

The IPV sample included all individuals who met the inclusion criteria of self-identifying as Tsimané and female, who married at least once, who only married monogamously, and who reported no use of modern birth control. Once IPV sample eligibility was determined, households were selected randomly within villages; <10% of women refused to participate in the IPV interview. Women ranged between 15 and 77 years of age at the time of the IPV assessment. The mean ± s.d. age at first marriage for women and their husbands was 16.7 ± 3.0 years (n = 105) and 20.5 ± 4.2 (n = 133), respectively (for additional descriptive statistics see Supplementary Tables 1 (wives) and 2 (husbands)). Of the 105 wives, 26 (25%) remarried (n = 28 marriages, since two women remarried twice), usually because of divorce (21/28, 75% of remarriages) rather than a first husband's death (7/28, 25%); divorce was most common in the first year of marriage (29% of divorces), and 76% of divorces occurred in the first 3 years. For women who divorced, there was no significant difference in the IPV prevalence or annual IPV rate for first versus subsequent marriages.

A retrospective design for IPV assessment was used for several reasons: (1) to estimate women's total IPV exposure during the sample period (that is, not just in the past year but in all years of marriage before menopause); (2) to examine intra-individual change in IPV exposure over time (for example, across births within marriage, as well as across marriages); and (3) to balance gains in statistical power from repeated measures on the same woman and logistical constraints of increasing sample size. We first elicited women's complete reproductive histories to construct multiple temporal intervals per woman (for example, pregnancies and periods from a given birth until weaning), to which we could assign to each interval a chronological year (hereafter marital risk year) using existing THLHP demographic data (range: 2–35 marital risk years for 105 women; a detailed description of demography data collection methods is provided elsewhere[47]). Aside from pregnancies and periods from a given birth until weaning, another type of temporal interval for which we assigned chronological years included the period of spousal co-residence before the first pregnancy in marriage (usually encompassing only one risk year). Additional types of intervals assigned chronological years included the year before the IPV interview (that is, for reproductive-aged women who had been neither pregnant nor lactating for at least 2 years (max = 21 years) before the interview), the period following a miscarriage until either the next pregnancy or the following year (the latter for women who were post-menopausal at the time of interview and whose final pregnancy resulted in miscarriage), and if applicable, the year before menopause (last interval). While interval duration is not chronologically uniform and does not span exactly one year, the Tsimané—who have no written language or time-keeping technology of their own—do not appeal to calendar dates to recall the timings of past events, but instead appeal to salient reference periods comprising major life-history events (for example, births or deaths). The derived temporal intervals provided women with these salient reference periods, during which they recalled IPV exposure, and during which we assigned relevant time-varying or invariant covariates. For intervals including pregnancies, women were asked whether IPV occurred before or during pregnancy; while most abusive episodes were reported before pregnancy, IPV may be under-reported during the first trimester. Because a major goal of this study was to test whether IPV increases marital fertility, intervals analysed here only span marital years in which a wife is at risk of birth (wife's age range: 11–45 years); for post-menopausal interviewees (23% of interviewees, contributing 37% of marital risk years (704/1,905)), age was capped at 45 years during their last interval (that is, no risk years beyond the age of 45 were included in analyses, nor were they included in the 1,905 marital risk years). In total, 1,165/1,905 risk years (61%) did not include pregnancy and the remaining 39% (740/1,905) included pregnancy.

To ascertain IPV, we asked women during each interval whether they were ever intentionally physically hurt by their husband; for example, from being punched, slapped, kicked or hurt in other ways mentioned in the Revised Conflict Tactics Scales[48] (for example, pushed, grabbed, choked, burned, bitten or hit with an object). While women reported various ways in which they experienced IPV, we did not systematically distinguish among them with separate questions because there was no compelling theoretical reason to do so, and because this would have greatly lengthened the interview (which already took 1–2 h). Thus, during each interval (for example, "From the time that you first realized that you were pregnant with baby X, until you gave birth to baby X…"), women were asked whether (and the number of times) they experienced any physical IPV. From these retrospective data, we were able to calculate, for each woman in a given year of a given marriage, both the cumulative frequency and the cumulative relative frequency of IPV (see Fig. 1); the cumulative relative frequency was calculated by computing a running total—across all years of a marriage—of the number of abusive episodes per year, and then for each year dividing that running total by the total number of abusive episodes in a marriage.

Couple-level data (that is, reports from spouses from the same marriage) collected in a subsample of 21 couples from 1 village in 2010 revealed substantial spousal consistency in reporting both whether physical IPV occurred in the year before the IPV interview (Fisher's exact P = 0.028) and the number of IPV incidents that same year[40]. Verbal spousal aggression, including threats of physical IPV, was often reported, but we excluded this from our IPV definition to focus on more salient behaviours exhibiting greater gender inequality[49]. We did not enquire about sexual IPV to minimize study intrusiveness and the risk of further traumatization.

Reproductive histories were elicited among women and men by M.G., J.S. and Tsimané research assistants, and updated by THLHP physicians and their translators during annual medical exams. Birth years were assigned based on a combination of methods described elsewhere[47]. The interbirth interval refers to the number of months between live births for women with two or more live births.

Height and weight were measured during THLHP medical exams using a Seca stadiometer (Road Rod 214) and Tanita scale (BF680). Schooling and Spanish fluency were assessed during annual THLHP census updates.

As part of a broader interview on kin cooperation and conflict, female participants and their husbands in three villages reported the frequency with which they witnessed and experienced physical violence during childhood, as perpetrated by co-resident male and female household heads (usually biological parents). Respondents used a five-point scale (1 = never, 5 = always) for three items regarding the frequency of a father's physical aggression towards: (1) his spouse; (2) ego; and (3) ego's siblings, and three items regarding the frequency of a mother's physical aggression towards: (1) her spouse; (2) ego; and (3) ego's siblings (see Supplementary Tables 8 and 10 for item descriptives).

Five items were used to assess men's attitudes towards intersexual control. Using a five-point scale (1 = strongly disagree, 5 = strongly agree), husbands in three villages indicated their beliefs about whether: (1) they can solely decide when their wife visits other houses; (2) they can solely decide when spousal intimacy occurs; (3) their wife should comply with their request regardless of her own

preferences; (4) their wife should respect their demand that she stop talking; and (5) they should be unrelenting sexually towards their wife (see Supplementary Tables 8 and 11 for item descriptives).

Three items were used to assess men's attitudes towards intrasexual physical aggression. Using the same five-point scale, husbands in three villages indicated their beliefs about whether: (1) it is vital for them to know how to physically fight another man; (2) they should hit another man if that other man hits them first; and (3) the use of physical force is more vital than intellect to resolve conflicts between men (see Supplementary Tables 8 and 12 for item descriptives). To assess external validity, we compared intrasexual aggression component scores (from a principal components analysis (PCA); see next paragraph) for men who reported engaging in a physical altercation with another man in the past year (18% of men) versus men who reported no such altercation (82%). As expected, if men's reported attitudes towards intrasexual physical aggression reflected actual aggression towards other men, men who reported an altercation had higher intrasexual aggression component scores (mean ± s.d. = 1.19 ± 0.96) versus men who reported no altercation (−0.26 ± 0.81; Mann-Whitney U-test, $P < 0.001$, $n = 50$).

Mann-Whitney U and chi-squared tests were used to compare spousal characteristics versus whether a wife experienced IPV (Supplementary Tables 1 and 2). PCAs were used to quantify men's attitudes towards intersexual control and intrasexual aggression, and men's and women's degree of childhood exposure to physical violence (see Supplementary Tables 8–13 for item, composite and PCA descriptives). In total, 6 PCAs yielded 6 components: ego's father's aggression (73% variance explained for the husband, 62% for the wife), ego's mother's aggression (67% for the husband, 58% for the wife), a husband's intersexual control (52%) and a husband's intrasexual aggression (57%). GEE analyses were used to model the effects of predictors on fertility and IPV rates. The GEE method accounts for the correlated structure of a dependent variable arising from repeated measures on the same individual over time, controlling for each individual. There is no standard absolute goodness-of-fit measure with the GEE method[50], which does not make distributional assumptions and uses a quasi-likelihood rather than full-likelihood estimation approach. A stepwise approach is used to fit GEE models; starting from a reduced model that included primary predictors, covariates were added sequentially and retained until all predictors were significant at $P \leq 0.1$. Village dummies were also included as fixed effects in all regressions, to account for potential village-level differences in fertility or reporting IPV. We compared GEE model estimates with those obtained from generalized linear mixed models fit by maximum likelihood, but no major differences were found. GEE parameter estimates are reported as ORs or predicted probabilities. We used a related-samples Wilcoxon signed rank test to test whether any IPV experience with a husband was associated with greater annual fertility with that husband within women across marriages. To provide variance estimates of annual fertility, we used bootstrap resampling to derive 95% CIs (Fig. 3). Participants with missing data were removed from the analyses.

Reporting Summary. Further information on experimental design is available in the Nature Research Reporting Summary linked to this article.

Data availability. The data that support the findings of this study are available from the corresponding author upon request.

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Author contributions

The conception, design and implementation of the study were developed by J.S. and H.K. J.S. collected the data. M.G. assisted in the collection of the demography data. J.S. analysed the data. All authors contributed to the interpretation of data analysis and drafting of the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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Behavioural & social sciences

Study design

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Study description	Quantitative, retrospective.
Research sample	Tsimane forager-horticulturalists of Bolivia; representative sample of women 15-77 years of age when the study was conducted (N=105); representative sub-sample of the husbands of these 105 wives (N=52 husbands).
Sampling strategy	Random sampling; sample size was not pre-determined and it was limited by time and resource constraints.
Data collection	Pen and paper; aside from subject and researcher, no one was present during data collection (except in some cases infants or toddlers of women being interviewed). The researcher was not blind to the study hypotheses during data collection.
Timing	Data were collected in three "waves", first in 2007, then in 2010, and then in 2011. First wave data were collected in two villages, second wave data in one village, and then third wave data in two villages.
Data exclusions	No data were excluded.
Non-participation	<10% of women refused to participate in the study, usually because of subsistence work obligations.
Randomization	Participants were not allocated into experimental groups.