



The Trivers-Willard Effect for Educational Investment: Evidence from an African Sample

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Abstract

The Trivers-Willard hypothesis (TWH) states that individuals in good condition favor offspring of the sex that has a higher variance in reproductive value. Empirical studies with historical human populations suggest that the TWH might explain biased birth-ratios as well as biased parental investment in male or female offspring. However, empirical tests of the TWH in modern human populations are less conclusive.

In this study, we investigate whether parental investment in education might be skewed according to the TWH in an African sample ($N=314$) that includes students from 8 different countries. The data show that male students who rate their family's wealth high tend to report more parental involvement in their own education, whereas the opposite is true for female students. This pattern is in accordance with the TWH for parental investment. The results support the validity of evolutionary explanations of behavioral bias in the context of parental investment in offspring education.

Keywords Trivers-Willard hypothesis · Parental investment · Investment in education · Gender differences in education

Introduction

The Trivers-Willard hypothesis (TWH) states that natural selection favors parents who adjust their offspring sex-ratio according to their own condition (Trivers & Willard, 1973). Specifically, parents in good condition are predicted to preferentially produce the sex with the higher variation in reproductive value (usually males), whereas parents in bad condition should favor the opposite sex (usually females). Moreover, Trivers and Willard hypothesized that the allocation of parental investment between offspring of different sexes should follow the same pattern (Trivers & Willard, 1973).

The TWH has been studied in a wide variety of species (Cameron & Linklater, 2007; Charnov et al., 1981; Clutton-Brock et al., 1984, 1986; Mealey & Mackey, 1990), including humans (Almond & Edlund, 2007; Anderson &

Crawford, 1993; Cameron & Dalerum, 2009; Salmon & Hehman, 2021; Schnettler, 2013; Volland & Dunbar, 1995). Although there is strong support for the TWH in some species, empirical evidence is far from conclusive (Brown, 2001; Brown & Silk, 2002; Cameron, 2004; Kolk & Schnettler, 2013, 2016; Lazarus, 2002; Pollet & Nettle, 2010; Sheldon & West, 2004; Willführ & Störmer, 2015). One possible reason why many studies fail to find a Trivers-Willard effect (TWE) is that the specific prediction made by Trivers and Willard is only valid under very restrictive conditions. First, parental condition needs to be passed on from parents to offspring. Second, offspring condition needs to be predictive of offspring reproductive value (and, thus, parental fitness). And third, the fitness function needs to be steeper for one of the sexes than for the other. Schindler et al. (2015) point out that only few empirical studies pay attention to these conditions, thereby neglecting that fitness-optimal offspring sex-ratios may in fact deviate from the original TWH. Moreover, recent theoretical work suggests that the long-term evolutionary dynamics of the TWE may differ considerably from what we would expect given the current offspring reproductive values (Borgstede, 2021).

The situation becomes even more complex when the TWH is tested with regard to parental investment after birth, rather than offspring sex-ratio. Although several studies find

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evidence in support of the investment TWH (Bereczkei & Dunbar, 1997; Cameron & Linklater, 2000; Cronk, 1989; Fujita et al., 2012; Hewison & Gaillard, 1999; Hinde, 2007; Hopcroft, 2005; Pink et al., 2017), there are also many studies that support the opposite (Byers & Moodie, 1990; Cronk, 2007; Hinde, 2009; Keller et al., 2001; Mattingly & McClure, 1985; Moses et al., 1998; Sikes, 1995, 1996). These inconsistent findings raise the question whether it is actually theoretically justified to apply the TWH to parental investment. The problem is that the evolutionary value of a conditional rule (such as “invest more in the offspring with a higher variance in reproductive value”) does not depend on the absolute fitness that is accomplished by the rule, but on the relative gain in reproductive value that results from it (cf. Borgstede, 2020). In the context of the TWE, this would imply that the conditions that are sufficient for a skewed offspring sex-ratio may lead to different predictions with regard to parental investment after birth (Carranza, 2002; Choi et al., 2022; Keller et al., 2001; Lazarus, 2002; Luo et al., 2016; Scheunpflug, 2006). For example, Borgstede (2019a) showed that, given equal effects per unit of parental investment for male and female offspring, natural selection will eventually favor a general bias towards the sex with the higher variance in reproductive value, irrespective of parental condition. The reason is that once an offspring is born, the evolutionary benefits of parental investment only depend on the *marginal* gain in offspring reproductive value per unit of investment. Therefore, it is always preferable to invest in the sex where more is to gain. Moreover, the existing literature has largely neglected the qualitative aspects of parental investment. For example, parents may preferentially invest one resource (e.g., time) in one offspring, but another resource (e.g., food) in another offspring, depending on the relative expected gain in reproductive value. Furthermore, the effects of parental investment on offspring condition may be expressed in various domains, which may, in turn, have different effects on male and female reproductive value. In humans, for example, financial wealth has a stronger effect on male than on female reproductive value, whereas physical attractiveness has a stronger effect on female than on male reproductive value, possibly yielding different TWEs for the two domains (cf. Borgstede, 2019a; Kanazawa, 2007). Such considerations may be neglectable in theoretical models where parental investment is treated as a single number. However, in empirical applications one can hardly find a single variable that captures all parental investments. Instead, it is necessary to find reasonable proxies for parental investment. Especially in humans, such proxies are diverse and only cover one aspect of parental investment (e.g., time till weaning, relative time spent with a particular offspring, or expenses for formal education), while neglecting the other (cf. Thouzeau et al., 2023). Given

that the expected marginal gain in reproductive value may not only depend on offspring sex but also on the type of investment, it is important to consider the relative gains of particular types of investment for males and females separately. In other words, parental investment in one domain (e.g., formal education) may be skewed according to the TWH, whereas parental investment in another domain (e.g., socially agreeable behavior) may follow a completely different pattern.

In this study, we apply the TWH to a sample of African students that come from eight different countries in fragile contexts. We focus on the effects of wealth (as an indicator of parental condition) on sex-biased parental investments in the formal education of male and female offspring. Although, following Borgstede (2019a), the overall amount of parental investment should be expected to be skewed towards the sex with the higher variance in reproductive value (in humans, this corresponds to males), the parental investment may be differentially allocated between male and female offspring depending on the type of investment. The population in this study consists exclusively of developing countries that have high social disparities between the upper and the lower class and a comparably low social meritocratic mobility (Corendea et al., 2012). Furthermore, in all countries from which the sample was drawn, gender roles are more strongly expressed than in most populations usually studied in the context of the TWH. These gender roles imply that the participation in competitive labor markets is generally lower for females than for males, as in these societies women carry the main responsibility for childcare, housework, and subsistence agriculture. As a result, high educational achievements are especially beneficial for males who already belong to the middle or upper class, whereas males and females from low-income households can only rarely increase their chances to move to a higher income class if they have a good formal education due to the generally low employment rates in countries with fragility (Hoffmann, 2015). We therefore hypothesize parental investments in the education of male offspring to be high when the family is wealthy and low when the family is not wealthy. Since females participate less in competitive labor markets, the benefits of high educational achievements are expected to be lower for high-income families when compared to male offspring. However, parents may also invest in their daughters' formal education to make them more competitive in marriage markets, especially when they come from an unwealthy family. Furthermore, long-term partner preferences in male and female humans suggest that it should be easier for an unwealthy woman to marry a wealthy man than it is for an unwealthy man to marry a wealthy woman (cf. Buss, 1989). Therefore, we hypothesize that parental investment in formal education will be higher for female offspring

Table 1 Pairwise correlations between educational investment ratings

	1.	2.	3.	4.
1. My parents help me with my homework (1–7)	-			
2. My parents ask me questions about school (1–7)	0.45*	-		
3. My parents offer help when I get bad marks at school (1–7)	0.42*	0.55*	-	
4. My parents care a lot about my education (1–7)	0.25*	0.59*	0.51*	-
5. My parents used to tell stories to me when I was little (1–7)	0.35*	0.37*	0.38*	0.38*

* $p \leq 0.05$

in low-income families when compared to investments in male offspring, whereas investment should be lower for female offspring from wealthy families when compared to male offspring. This pattern corresponds exactly to the original TWH: Wealthy parents are expected to invest more in male than in female offspring, whereas poor parents are expected to invest more in female than in male offspring.

Methods

The data used in this study were collected by the participants of an international masters' program. The participants of the program worked as teachers in eight different African countries. The sample used in this study was a (non-random) convenience sample consisting of the students of the teachers who participated in the masters' program. All data was acquired by means of questionnaires that were delivered to the participants' students at their respective workplaces. The students were instructed to fill out the questionnaire in class and return it to the teacher. All respondents had been informed about their right to deny being part of the study and of full anonymity. The questionnaire was first formulated in English and then translated into French. To ensure that both versions of the questionnaire were semantically equivalent, an independent back-translation was performed for each question. Following the fragile state index of 2022, all students participating in the survey are from "alarming fragile states" or states with a "warning on fragility" for the last twenty years (Fund for Peace, 2022).

Parental investment in education was assessed by self-rated agreement on a seven-point scale to a collection of five statements about parental support with regard to homework, interest in school and education, help with bad marks and telling stories. These questionnaire items were not intended to form a psychometric measurement scale but to assess educational investment as an abstract behavioral class (cf. Leising and Borgstede, 2019). Following Buntins et al. (2016), the arithmetic mean of the item responses can then be interpreted as the degree to which the students receive a high amount of investment in education from their parents, irrespective of the psychometric properties of the item set (cf. Borgstede, 2019b). Thus, the dependent variable in this

Table 2 Distribution of students over countries

Country	Count	Percentage
Burundi	23	7.3%
Cameroon	72	22.9%
D.R. of Congo	50	15.9%
Liberia	2	0.6%
Rwanda	103	32.8%
Tanzania	13	4.1%
Uganda	8	2.5%
Zambia	18	45.7%
Sum	289	92%
Missing	25	8%

study was constructed by calculating the arithmetic mean over the five numeric item responses. Table 1 presents the five items together with the pairwise correlations of the corresponding self-ratings. All correlations were significant on the 5% level with an overall internal consistency of $\alpha = 0.78$.

The independent variables in this study were the participants' self-rated sex ("Are you a boy or a girl?") and the subjective wealth of their family, which was assessed using a single item with a seven-point rating scale ("How would you rate your family's wealth on a scale from 1 (very poor) to 7 (very rich)?").

The participants' age was assessed by a single-choice item using eight successive three-year intervals. The midpoint of each interval was used as the estimated age in years. To control for the absence of one parent, a dummy variable was constructed from the participants' information about the composition of their household, indicating whether one of their biological parents did not live in the same household as the participant. Because parental resources are naturally limited such that a higher number of offspring reduces average investment per offspring, the number of siblings was calculated for each participant as the sum of self-reported older and younger brothers and sisters. Moreover, as indicators of the students' reading, math, science and social studies competencies, participants were asked to rate their own abilities in the respective subjects on a seven-point scale ranging from "very bad" to "very good" ("How would you rate your reading/mathematics/natural science/social studies abilities as compared to other students?"). Although self-rated competencies are known to be unreliable and likely to

be biased, they were included as control variables because parental investment in formal education may be affected by their children's competencies. Therefore, even if self-rated competencies are not as reliable as objective competence tests, they may still be useful as statistical controls. To compensate for sex-specific bias in self-rated competences (Hanover & Zander, 2020; Kampa et al., 2020; Ollrogge et al., 2022), the competence ratings were centered for male and female participants separately before the main data analysis.

Data analysis consisted in descriptive and multivariate statistics by means of the free statistics environment R, version 4.0.3 (R Core Team, 2020). Due to the hierarchical data structure (students nested within countries), a multilevel regression approach seemed to be indicated (Raudenbush & Bryk, 2002). To assess whether there was significant variation in average parental investment in education between the countries, a random-effects intercept only null-model was fitted using the R-package lme4 (Bates et al., 2015). The model had a singular fit ($ICC=0$), revealing that there was no variation explained by the random intercept. Therefore, the multivariate analyses were conducted using standard least-squares regression, instead. The models were successively extended by first adding the control variables, followed by the independent variables (sex and wealth) and the interaction term between sex and wealth. All numeric predictors were centered around the grand mean, such that the intercept designates the expected value of parental investment in education for an individual that has average values in all assessed variables. Effect estimates were calculated using the unstandardized variables to facilitate their interpretation. Because all numeric variables were assessed using the same scale, quantitative comparisons between statistical effects are still valid. Missing data were handled by multiple imputation (15 imputations with 15 iterations each) using the R-package mice (van Buuren & Groothuis-Oudshoorn, 2011). The models were fitted with each imputed dataset separately and then combined using Rubin's formulas (Grund et al., 2018) by means of the R-package mitml

(Grund et al., 2021). Model comparisons were performed by calculating separate likelihood ratio tests and then combining the results by evaluating the likelihood at the pooled parameter estimates as proposed by Meng and Rubin (1992). As a criterion of significance, an alpha of 0.05 was chosen for all statistical significance tests. Since the data were obtained from a non-probabilistic convenience sample, the obtained p-values are best interpreted as approximations to permutation tests. Permutation tests do not require random sampling but merely pairwise exchangeability, which is a much weaker assumption (Good, 2005). The permutation test interpretation implies that statistical significance should be interpreted as an indicator of internal validity (Edgington & Ongheena, 2007), leaving the question of external validity to a (non-statistical) bottom-up generalization strategy as outlined in Borgstede and Scholz (2021).

Results

The original sample consisted of 323 students from primary, secondary, and vocational schools. The students were from 8 different African countries. 103 students were English-speaking and 220 were French-speaking. 9 participants reported that both their parents were deceased at the time of the study and were therefore excluded from all further analyses. Table 1 summarizes the distribution of the remaining 314 individuals over the countries. 48% of the subjects indicated they were male and 50% indicated they were female. 2% did not provide information about their gender.

The mean age of the students was 19.5 years ($SD=3.73$ years), with values ranging from 11 years to 32 years. Table 3 summarizes the main descriptives of the assessed variables. The data show that all variables show a substantial amount of variation and that missing values are rare for most variables except the reported number of siblings.

The results of the multivariate analyses are presented in Table 4. In Model 1 only the control variables are included. The model explains 16% of the total variance in parental investment in education. A pooled likelihood ratio test indicates that the model has a significantly better fit than the null model. The intercept indicates that an individual with an average value in all control variables has an expected parental investment in education of 4.92 (on a scale from 1 to 7), which is significantly larger than zero. Parental absence has a significant negative effect of -0.9 scale points, indicating that students who live in the same household as their parents receive substantially more educational investment than students who do not share a household with their parents. The number of siblings also has a small, but significant, negative effect on parental investment in education (-0.06 scale points of investment per additional child), supporting

Table 3 Descriptives of the assessed variables

Variable	Mean	SD	Min	Max	Missing
Age (years)	19.5	3.73	11	32	1
Number of siblings (count)	5.59	3.06	0	17	37
Wealth (1–7)	4.03	1.62	1	7	0
Science competence (1–7)	5.14	1.29	1	7	1
Math competence (1–7)	4.69	1.57	1	7	2
Reading competence (1–7)	5.69	1.22	1	7	1
Social studies competence (1–7)	5.43	1.24	1	7	1
Help with homework (1–7)	3.75	2.07	1	7	1
Questions about school (1–7)	5.12	1.96	1	7	1
Offer help with bad marks (1–7)	4.43	2.19	1	7	3
Care about education (1–7)	5.87	1.57	1	7	1
Tell stories (1–7)	4.94	2.00	1	7	1

Table 4 Results of multiple regression models predicting parental investment in education

	Model 1		Model 2		Model 3	
	Estimate (SE)	<i>p</i>	Estimate (SE)	<i>p</i>	Estimate (SE)	<i>p</i>
Linear effects						
Intercept	4.92 (0.08)	<0.001	4.90 (0.11)	<0.001	4.88 (0.11)	<0.001
Parental absence	-0.90 (0.23)	<0.001	-0.80 (0.21)	<0.001	-0.76 (0.21)	<0.001
Number of siblings (count)	-0.06 (0.03)	0.059	-0.07 (0.03)	0.017	-0.08 (0.03)	0.009
Age (years)	-0.07 (0.04)	0.001	-0.05 (0.02)	0.017	-0.05 (0.02)	0.024
Science competence (1–7)	0.24 (0.07)	0.001	0.16 (0.07)	0.026	0.19 (0.07)	0.006
Math competence (1–7)	-0.01 (0.06)	0.922	0.04 (0.05)	0.502	0.05 (0.05)	0.343
Reading competence (1–7)	-0.08 (0.07)	0.250	-0.08 (0.07)	0.208	-0.13 (0.07)	0.053
Social Studies competence (1–7)	0.04 (0.07)	0.559	0.03 (0.07)	0.613	0.03 (0.07)	0.686
Wealth (1–7)			0.28 (0.05)	<0.001	0.13 (0.07)	0.052
Sex (male)			0.01 (0.15)	0.942	0.01 (0.15)	0.934
Wealth*Sex					0.29 (0.10)	0.003
<i>R</i> ²	0.16		0.25		0.27	
Model comparisons ^a						
Model 1 vs. Null Model	<i>p</i> < .001					
Model 2 vs. Model 1			<i>p</i> < .001			
Model 3 vs. Model 2					<i>p</i> = <0.001	

^aPooled likelihood ratio tests

the theoretical argument that individual parental investment tends to decrease with a higher number of offspring. The negative age effect of -0.07 scale-points per additional year indicates a small but significant tendency to invest less in older children. Of the self-rated abilities, only science competence has a significant effect (0.24 scale-points of investment per scale-point difference in ability rating).

In Model 2 the two independent variables (family wealth and student sex) were added. The model explains 25% of the total variance. The pooled likelihood ratio test indicates a significant increase in model fit when compared to Model 1. The effect estimates of the control variables remained largely unchanged (however, all significant effects are a bit smaller than in Model 1). Model 2 also shows a significant positive effect of self-rated family wealth (0.28 scale-points of investment per scale-point difference in wealth rating) but no significant sex differences.

In Model 3 the two-way interaction between self-rated family wealth and the participants' sex was added as an additional term. The full model explains 27% of the total variance in parental investment in education. Like before, the overall model fit was compared to the preceding model using a pooled likelihood ratio test. The test indicates that Model 3 has a significantly better fit than Model 2. The effect estimates for the control variables remain largely unchanged when compared to Model 2. However, by including the interaction term, the main effect of wealth is more than halved and no longer significant. The interaction term itself is positive and significant (0.29 additional scale-points of investment per scale-point difference in wealth rating for males), indicating that the effect of wealth on

parental investment is significantly higher for males than it is for females.¹

The interaction effect is illustrated in Fig. 1. The figure shows the pooled marginal effects of wealth ratings on parental investment in education for male and female participants. As predicted by the Trivers-Willard hypothesis, the two lines cross such that expected parental investment is higher for girls than

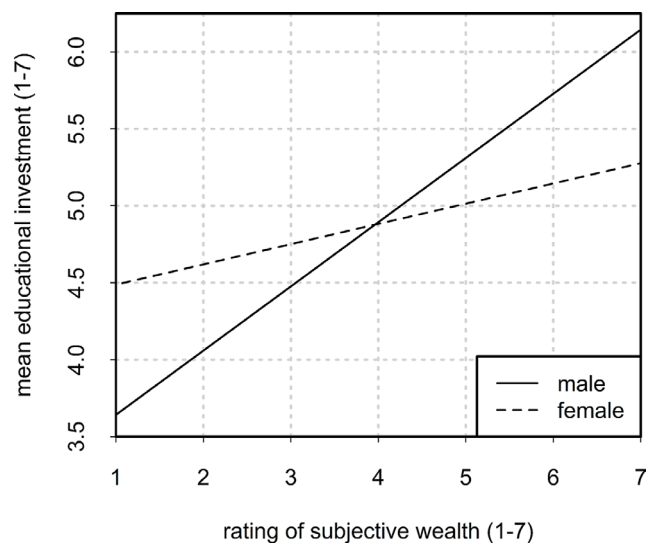


Fig. 1 Interaction between wealth and sex with regard to parental investment in education (pooled marginal effects)

¹ As a robustness check, Model 3 was also fitted without the control variables. The interaction term in the reduced model hardly changed (0.24 instead of 0.29) and remained significant (*p* = .011). The variance explained by sex, wealth and their interaction alone was 16% (*p* < .001).

for boys when the family's wealth is rated low, and expected parental investment is higher for boys than for girls when the family's wealth is rated high.

Discussion

This study presents new evidence to support the Trivers-Willard hypothesis with regard to parental investment in education. Based on a student sample from eight African countries, multivariate analysis shows that there is a significant interaction between family wealth and offspring sex with regard to parental investment in education. Whereas girls receive more parental investment than boys in poor families, boys receive more investment than girls in wealthy families. This result is in line with the hypothesis of sex-differential parental investment as it is derived from evolutionary theory.

The data further show that all children seem to receive at least some amount of parental support with their formal education. The best predictor of parental investment was the presence of at least one parent (note, however, that some students reported a high amount of parental investment despite living separate from their parents). Moreover, younger students reported more parental investment than older students. The latter result is hardly surprising, given the great age range (11 to 32 years), which includes students who have been adults for more than ten years. Students who had many siblings (up to 17 in the present sample) reported a smaller average parental investment in their education. This indicates that there is at least some degree of competition between offspring for their parents' resources. The effect seems rather small, which indicates that parental investment in education might be partly shared among offspring. However, it is equally possible that students rated their received parental investment relative to the amount of parental investment received by their siblings.

Self-rated abilities in school related subjects only yielded significant results with regard to science competence. This effect may indicate that students with higher science abilities are conceived as having a higher potential to successively compete for high-wages jobs and are thus supported more than students with lower science abilities (cf. Ehrtmann and Wolter, 2018). Another possible explanation might be that students benefit most from parental investment in education with regard to science competence. However, it remains open why the other competences (math, reading and social studies) should be less affected by parental support than science competences. Therefore, it seems more plausible that parents adapt their investment strategies to their childrens' potential, rather than the other way around.

The main limitation of the study consists in the use of subjective self-assessments. Such ratings may be biased (e.g., with regard to abilities) or unreliable because students may have limited knowledge about the underlying states of affairs (e.g., the actual family income). Moreover, the use of an ad-hoc numeric measure of parental investment may be questioned with regard to its validity and reliability. However, such critique would only apply if the used items were interpreted as indicators of an underlying latent variable, which they are not. Instead, the construct of parental investment is taken to be an abstract behavioral class that includes the activities assessed in the items as paradigmatic examples. In other words, by parental investment we mean exactly the things we asked in the questionnaire. Thus, questions of psychometric scale properties are not essential to the validity of the mean item responses as an indicator of parental investment (cf. Buntins et al., 2016).

One specific strength of the study is the population from which the sample was drawn. Many other studies on educational investment use samples from developed countries (mostly Europe and the USA), where parents tend to have fewer children and the average wealth is considerably higher than in most African countries. In other words, many studies on educational investment focus on western, industrialized rich democratic (WEIRD) populations (Henrich et al., 2010). However, in populations with a low variance in resources and low variance in reproductive success, one would expect only weak or no skewed parental investment in the sense of a TWE. The lack of variance in resources and reproductive success in many studies using western populations might explain why the evidence on the TWE in humans is still inconclusive. On the other hand, our sample includes students from a very diverse educational and social background, with some students at school being over 30 years old, and some coming from extremely poor families. Furthermore, due to strong traditional gender roles in many African countries, the expected returns of educational investments can be expected to differ considerably between male and female offspring. Since in these countries, women participate less in competitive labor markets than men, the expected gain in wealth by formal education is, on average, highest for male offspring from wealthy families (Anyanwu & Augustine, 2013; Schwidrowski et al., 2021). The combination of large expected sex differences and a wide range of objective wealth makes our sample particularly suitable to test the Trivers-Willard hypothesis for parental investment.

Our results contribute to the ongoing debate whether the Trivers-Willard effect may explain differential treatment of male and female offspring in humans. With regard to formal education, we found that male offspring tends to be supported more in middle-, and upper-class families, whereas in lower class families, female offspring tends to receive more

parental support. Although the latter effect may seem like an effect of ongoing women's empowerment (UNESCO, 2019), our results indicate that the apparent educational advantage of girls in low-income families might actually be the result of persisting gender roles that ultimately yield sex-specific parental investment in the sense of a Trivers-Willard effect as an evolutionarily stable strategy.

Authors' contributions MB conducted the data analysis and wrote the first draft of the manuscript. Both authors contributed to the final version of the article.

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Data Availability Data and code will be made available on request.

Declarations

Ethics approval and consent to participate Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements.

Consent for publication All participants were informed about the aims of the study, including future publications, before they were asked for their consent to participate.

Consent to participate The patients/participants provided their written informed consent to participate in this study.

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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