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Original Research

Erectile dysfunction in copper and cobalt miners: a cross-sectional study in the former Katanga province, Democratic Republic of the Congo

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Abstract

Background: The African Copperbelt is a site of intense artisanal and industrial mining and refining of copper and cobalt.
Aim: We aimed to investigate factors that are possibly associated with erectile dysfunction (ED) in metal miners in the former Katanga province of the Democratic Republic of the Congo.
Methods: In a cross-sectional study of 138 miners and 139 controls (bakers), we administered questionnaires to obtain sociodemographic and occupational data and to assess male sexual function (International Index of Erectile Function [IIEF]) and marital relation quality (Revised Dyadic Adjustment Scale). Furthermore, we measured trace metals in blood and urine, as well as testosterone and thyroid hormones in serum.
Outcomes: Outcomes included the prevalence of questionnaire-derived ED and the relation of ED with individual characteristics, serum testosterone, and environmental factors.
Results: Miners were on average 4 years older than bakers (mean ± SD, 37.5 ± 6.9 vs 33.3 ± 5.7 years). Miners had significantly lower scores than bakers on the IIEF (median [IQR], 66 [49-73] vs 73 [66-74]) and the 3 domains of the Revised Dyadic Adjustment Scale (consensus, satisfaction, cohesion). Free testosterone was significantly lower in miners than bakers (ng/dL; 8.11 [6.90–10.10] vs 10.52 [8.83-12.58]; $P < .001$). In miners, sex hormone–binding globulin correlated positively with blood Pb and urinary Cd. In a multivariable analysis, mild to moderate ED or moderate ED (IIEF–erectile function score ≤18) was significantly associated with having a mining-related job (adjusted odds ratio [aOR], 2.6; 95% CI, 1.3-5.3), work seniority >5 years (aOR, 2.3; 95% CI, 1.1-4.6), alcohol consumption (aOR, 2.8; 95% CI, 1.2-6.7), and aphrodisiacs use (aOR, 4.2; 95% CI, 2.2-8.0). Mediation analysis showed that marital relationship partially mediated the relation between work seniority >5 years in mining and ED.
Clinical Implications: The high prevalence of ED found in artisanal mine workers indicates that work-related factors should be considered as possibly contributing, directly or indirectly, to sexual dysfunction in men.
Strengths and Limitations: Strengths include being the first epidemiologic study documenting ED with validated questionnaires and its possible determinants, including exposure to toxic metals, among young artisanal miners vs a suitable control group. Limitations are the cross-sectional design with convenience sampling and absence of objective confirmation of ED.
Conclusion: As compared with controls, miners reported poorer sexual function and lower quality of their marital relationship, and they had lower free testosterone levels, which may be due to their high exposure to trace metals.

Keywords: Copperbelt; mining metals; global health; male sexual health.

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Introduction

Erectile dysfunction (ED) is defined as the inability to achieve and/or maintain an erection sufficiently rigid for obtaining satisfying sexual intercourse.[1] While ED mainly affects men aged between 40 and 70 years,[2] recent studies reported that ED is becoming highly prevalent, even in men aged <40 years.[3]

Classical pathogenic risk factors for ED include clinical disease states (eg, diabetes, hypertension, obesity), trauma to the pelvic and/or genital region, iatrogenic effects of medical and surgical interventions, as well as lifestyle and/or behavioral factors (eg, tobacco, alcohol, unhealthy dietary habits). It was recently suggested—with limited hard evidence—that exposure to harmful biological or chemical substances in the general or occupational environment could also play a role in the pathogenesis of ED.[4]

The southern part of the former Katanga province, situated in the African Copperbelt, is a site of intense mining and mineral processing, with thousands of men working as diggers (*creuseurs*) in artisanal mines and as laborers in metal-processing companies.[5] The working conditions in copper and cobalt mining in Katanga are generally poor and harsh[6] and imply that mine workers are heavily exposed to trace metals, mainly cobalt, but also a variety of accompanying toxic elements, such as arsenic, uranium, manganese, cadmium, and lead.[7]

Metals can constitute significant threats to human health. Various trace metals, such as cadmium, cobalt, arsenic, lead, manganese, and mercury, are well known to have toxic effects on several organ systems, including the kidneys, respiratory system, central nervous system, and, to some extent, endocrine system.[8,9] However, until now, little is known about their effects on erectile function in men.[10] Only 2 studies, recently conducted in populations from the United States, have reported on associations between ED and trace metal exposures.[11,12]

Given our observations combined with clinical experience suggesting that ED is a frequent complaint among mine workers in the area, we did an exploratory case-control study in Lubumbashi, the capital of Katanga, and found a significant association between reporting ED and having a mining-related job.[13]

In the present study, among a large number of mostly young mine workers and suitable control men (age <40 years), we aimed to find answers to the following questions: (1) What is the prevalence of ED among mine workers vs control men? (2) Which factors, including exposure to trace metals, are possibly associated with ED among mine workers?

Methods

Study setting and recruitment modalities

In a cross-sectional study conducted between December 2018 and September 2020, we included 138 miners and 139 bakers from various mining cities (Lubumbashi, Likasi, Kipushi, Fungurume, and Kolwezi) in the Haut-Katanga and Lualaba provinces that make up the Congolese part of the African Copperbelt.[14] The miners were artisanal diggers and workers in processes downstream of mining (ie, transporting, washing, and sieving; crushing ores) from 2 regions according to the main ores mined: the copper and cobalt region (Lubumbashi, n = 41; Likasi, n = 4; Tshabula, n = 25; Kolwezi, n = 36) and the copper, lead, and zinc region (Kipushi, n = 32). The bakers were employed in industrial bakeries and came from Lubumbashi (n = 110), Likasi (n = 24), and Fungurume (n = 5), with most of them having been included in a previous study.[15] All participants were recruited at their workplaces. This means that (1) all workers present at the workplace at the moment of the study visit were invited to participate and (2) those giving their oral and written informed consent replied to the questionnaires and provided samples of urine and venous blood. All procedures were done before 11 AM at the worksite, with respect for privacy. Few eligible persons declined to participate. The study protocol for this study was approved by the Committee of Medical Ethics of the Université de Lubumbashi (UNILU/CEM/144/2018).

Study procedures

For all participants, we obtained information on demographic data by means of a paper questionnaire that was generally self-administered but sometimes face-to-face for participants with low literacy.

To assess male sexual function, we used the International Index of Erectile Function (IIEF) questionnaire,[16] which provides scores for 5 domains (erectile function, orgasmic function, sexual desire, satisfaction with intercourse, and general satisfaction) and a total score for male sexual function. For categorical classification of ED,[17] we used 2 cutoff scores for the IIEF–erectile function domain (IIEF-EF): ≤24 (ie, including mild ED) and ≤18 (excluding mild ED). The IIEF has good psychometric quality, and the internal consistency in the current sample was excellent (Cronbach α = 0.98).

To assess marital relation quality, we used the revised version of the Dyadic Adjustment Scale (RDAS; 14 items).[18,19] The cutoff score for the RDAS was 48 such that scores ≥48 indicated nondistress and ≤47 indicated marital/relationship distress. The reliability of the RDAS for all participants was acceptable (Cronbach α = 0.73).

Both questionnaires were translated into Swahili (Appendix) from their original English versions by using the forward-backward translation method to check for accuracy.

At the end of the interview and with the participant having remained seated, blood pressure was measured with the M3 HEM-7131-IntelliSense Blood Pressure Monitor (OMRON Healthcare). Height and weight were measured with a rod and a SECA scale, respectively. Body mass index (BMI) was calculated. Finally, participants were invited to give a spot sample of urine and 2 venous blood samples.

Sample treatment and analyses

Serum concentrations of testosterone, sex hormone–binding globulin (SHBG), thyroxin, and thyroid-stimulating hormone were measured by competitive immunoassay with ECLIA technology on a COBAS e801 instrument (Roche Diagnostics). Free testosterone was calculated with the Vermeulen formula.[20] In 18 serum samples, testosterone was also determined by liquid chromatography–tandem mass spectrometry.[21] Urine and blood samples for trace metals were treated and measured as previously published[7] and are described in detail in the online supplement.

Statistical analysis

Statistical analyses were conducted with SPSS Statistics for Windows version 26.0 (IBM Corp) and Prism version 9.4.1

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(GraphPad Software). Statistical significance was defined as a 2-tailed P value $\leq .05$.

Data are presented as mean (SD) or median (IQR), depending on distribution (Shapiro-Wilk test). Differences between groups were assessed for statistical significance by Student *t*-test or Mann-Whitney *U* test, as appropriate, and for proportions by the Fisher exact test. We applied univariable and multivariable regression analysis models to test the association of ED—an IIEF-EF score ≤ 24 (model A) or ≤ 18 (model B)—and the following possible explanatory binary variables: having a mining-related job, age ≥ 40 years, work seniority >5 years, smoking tobacco, alcohol consumption, consumption of alcohol and tobacco, cannabis use, and aphrodisiacs use. Cronbach α was used to measure the internal consistency of the IIEF and RDAS.

In a mediation analysis model, we used the PROCESS macro version 4.2 (model 4; Andrew F. Hayes, University of Calgary) for SPSS[22] to test whether the relation between ED symptoms and work seniority >5 years could be mediated by a third variable. The bias-corrected 95% CI was calculated with 5000 bootstrapping resamples. We considered that the mediating effect was significant if the 95% CI of the indirect effect (path $a \times b$) did not contain 0.

Results

Sociodemographic parameters and questionnaires

Table 1 presents sociodemographic and other relevant characteristics of the 138 miners and 139 bakers. Miners were significantly older than bakers (mean ± SD, 37.5 ± 6.9 vs 33.3 ± 5.7 years); they were also significantly taller (+3 cm) and heavier (+3.4 kg), but both groups had similar low values for BMI, with a mean value of 23.6 ± 3.7 for the whole group and with only 4 participants in each group being obese (BMI >30). Values of arterial blood pressure did not differ between the groups, and just 1 miner reported a history of hypertension. Nobody indicated a history of diabetes.

Miners and bakers did not differ with regard to marital status and prevalence of having extraconjugal partners. However, more miners than bakers reported drinking alcohol, using aphrodisiacs, or taking phosphodiesterase 5 inhibitors.

IIEF and RDAS

Table 2 shows that miners had significantly lower scores than bakers in all domains of the IIEF. Thus, the total IIEF score was 7 points lower ($P < .001$) among miners than bakers (median [IQR], 66 [49-73] vs 73 [65-74]), with the most pronounced difference being observed for erectile function, which was lower by 5 points (median, 25 vs 30). Based on the clinical interpretation of the ED domain,[17] the prevalence of any ED (IIEF-EF score ≤ 24) was 47% in miners (Figure 1): 15.2% had mild ED (score, 19-24); 31.1%, mild to moderate ED (score, 13-18); 1 (0.7%), moderate ED (score, 7-12); and nobody had severe ED. Among bakers, the prevalence of ED was 17.3%: 5.8% had mild ED and 11.5% had mild to moderate ED; nobody had moderate or severe ED in this group. When comparing types of ED in both groups, we found a significant difference ($\chi^2 = 25.1$, $df = 1$, $P < .0001$). When the analysis was restricted to men <40 years old, the prevalence of questionnaire-defined ED was also higher among miners (46.5%, $n = 88$) than bakers (23.5%, $n = 123$; $P = .01$). Of the 4 miners who were obese, 1 had mild ED and 1 had moderate ED; of the 4 obese bakers, 1 had mild ED.

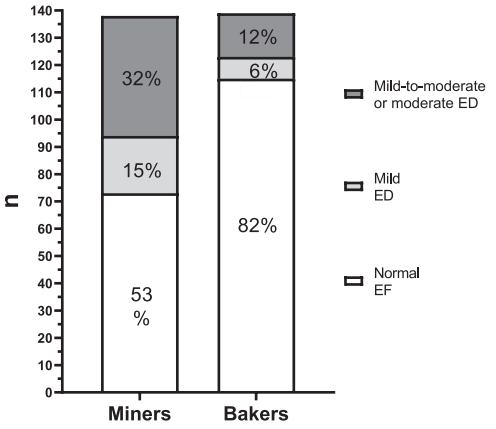

Figure 1. Prevalence of erectile dysfunction (ED) as assessed by the International Index of Erectile Function–erectile function domain (IIEF-EF) in 138 miners and 139 bakers. Normal erectile function, IIEF-EF ≥ 25 (maximum score, 30); mild ED, IIEF-EF ≤ 24; mild to moderate or moderate ED, IIEF-EF ≤ 18. The prevalence of ED was significantly higher among miners than bakers ($\chi^2 = 17.8$, $P < .001$).

In miners, IIEF-EF scores correlated significantly with IIEF-desire ($r = 0.7$, $P < .001$) but not with other domains.

As shown in Table 2, miners had significantly lower RDAS scores in all 3 domains of partner relationship quality (consensus, satisfaction, and cohesion), thus leading to 97% of miners exhibiting some degree of marital distress (score <48) as opposed to 23% of bakers ($P < .001$).

Laboratory results

Metals

For several trace metals, concentrations were, as expected, higher in blood or urine among miners than bakers (Table S1). In blood, miners had higher median concentrations than bakers for cobalt (3-fold), cadmium (1.4-fold), and lead (1.3-fold). In urine, median concentrations with creatinine correction were 1.2 to 3.7 times higher in miners than bakers for aluminium, vanadium, manganese, cobalt, copper, arsenic, cadmium, tin, and lead.

Hormones

The 2 methods used to measure serum testosterone (competitive immunoassay and liquid chromatography–tandem mass spectrometry) gave almost the same results in 18 samples (Figure S1), thus indicating that the competitive immunoassay method used in all participants was valid.

Free testosterone (median [IQR]) was slightly but significantly ($P < .001$) lower among miners than bakers (ng/dL; 8.1 [6.9-10] vs 11 [8.8-13]); however, only 1 mine worker had free testosterone levels suggestive of hypogonadism (<350 ng/dL or <12 nmol/L). Conversely, SHBG was significantly ($P < .001$) higher among miners than bakers (nmol/L; 52 [39-64] vs 41 [33-53]). We did not find significant differences between the groups for thyroid-stimulating hormone (mUI/L; miners, 1.5 [1.1-2.2]; bakers, 1.3 [0.87-1.9]; $P = .07$), but thyroxin was slightly but significantly higher in miners than bakers (pmol/L; 15 [14-16] vs 13 [12-15]; $P < .001$).

Table 3 shows Spearman correlations (ρ) between the various indices assessed among mine workers. No correlations were found between free testosterone and IIEF-EF scores.

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Table 1. Sociodemographic, medical, physiologic, and lifestyle characteristics of participants.[a]

Parameter	All ($N = 277$)	Miners ($n = 138$)	Bakers ($n = 139$)	P value[b]
Age (y)				
Overall	35 ± 7	36 ± 7	33 ± 6	<.001
>40 y	66 (24)	50 (36)	16 (12)	<.001
Relationship				
Married	257 (93)	131 (95)	126 (91)	.245
Single/divorced	20 (7)	7 (5)	13 (9)	.245
Extraconjugal partner	24 (9)	12 (9)	12 (9)	.837
No. of children	4 (2-6)	4 (2-6)	3 (2-5)	.07
Age of the last child, y	2 ± 2	2 ± 2	1 ± 1	.021
Weight, kg	68.1 ± 9.1	69.8 ± 8.9	66.4 ± 8.8	.001
Height, cm	170 ± 7	172 ± 6	169 ± 8	.001
Body mass index, kg/m^2	24 ± 4	24 ± 3	23 ± 4	.594
Arterial blood pressure, mm Hg				
Systolic	126 ± 13	126 ± 14	126 ± 11	.728
Diastolic	79 ± 10	80 ± 10	78 ± 10	.102
Resting heart rate, bpm	75 ± 12	75 ± 13	75 ± 11	.629
Current				
Alcohol drinking	102 (43)	59 (43)	43 (31)	.047
Tobacco smoking	69 (25)	39 (28)	30 (21)	.213
Cannabis smoking	16 (6)	10 (7)	6 (4)	.317
Use of local aphrodisiacs	90 (33)	59 (43)	31 (22)	<.001
Use of PDE5i	32 (12)	24 (17)	8 (6)	<.001
Hormones				
Testosterone,[c] ng/dL	558 (450-691)	527 (445-618)	582 (461-716)	.05
SHBG,[d] nmol/L	48 (37-58)	53 (39-64)	44 (33-53)	<.001
Free testosterone,[e] ng/dL	9 (8-12)	8 (7-10)	11 (9-13)	<.001
TSH,[f] mUI/L	1 (1-2)	2 (1-2)	1 (1-2)	.07
T4,[f] pmol/L	14 (13-15)	15 (14-16)	13 (12-15)	<.001

Abbreviations: PDE5i, phosphodiesterase 5 inhibitor; SHBG, sex hormone–binding globulin; T4, thyroxin; TSH, thyroid-stimulating hormone. [a]Values reported are mean ± SD, median (IQR), or No. (%). [b]P values are based on the Fisher exact test or Student t-test. [c]Total testosterone: 85 miners and 88 bakers. [d]SHBG: 85 miners and 89 bakers. [e]Free testosterone 83 miners and 88 bakers. [f]TSH and T4: 85 miners and 87 bakers.

Table 2. Scores on the IIEF and RDAS.[a]

Measure: Domain	Possible score	Miners	Bakers	P value[b]
IIEF[c]				
Erectile function	1-30	25 (18-30)	30 (29-30)	<.001
Satisfaction with intercourse	0-15	12 (9-14)	14 (12-14)	.007
Orgasmic function	0-10	10 (8-10)	10 (9-10)	.002
Sexual desire	2-10	8 (6-10)	10 (8-10)	<.001
Overall sexual satisfaction	2-10	8 (6-10)	10 (8-10)	<.001
Total	5-75	66 (49-73)	73 (65-74)	<.001
RDAS[d]				
Consensus	0-30	20 (18-23)	26 (23.7-29)	<.001
Satisfaction	0-20	15 (13-17)	17 (15-18)	<.001
Cohesion	0-19	10 (8-11)	10 (10-12)	<.001
Total	0-69	45 (41-49)	53 (49-56)	<.001

Abbreviations: IIEF, International Index of Erectile Function; RDAS, Revised Dyadic Adjustment Scale. [a]Values reported are median (IQR). [b]P values based on Mann-Whitney U. [c]IIEF: 138 miners and 139 bakers. [d]RDAS: 108 miners and 114 bakers.

Among miners, SHBG correlated with age ($\rho = 0.4$, $P < .001$), and free testosterone correlated inversely with age ($\rho = -0.3$, $P = .002$). SHBG correlated positively with blood Pb ($\rho = 0.4$, $P = .01$), blood Cd ($\rho = 0.3$, $P < .001$), creatinine-corrected urinary Cd ($\rho = 0.2$, $P = .03$), and Ni ($\rho = 0.3$, $P < .001$) and negatively with blood Hg ($\rho = -0.2$, $P = .04$). Thyroxin correlated with creatinine-corrected urinary Sn ($\rho = 0.46$, $P < .001$).

Logistic regressions

In univariable logistic regression analysis, ED (IIEF-EF score ≤24) was significantly related to the job, age ≥40 years, work seniority >5 years, tobacco smoking, and aphrodisiacs use (Table 4). In multivariable logistic regression analysis, only mining-related job (adjusted odds ratio [aOR], 3.1; 95% CI, 1.7-5.6; $P < .001$] and use of aphrodisiacs (aOR, 2.6; 95% CI, 1.5-4.8; $P < .001$) were significantly associated with ED (model A).

When these analyses were done with a stricter cutoff for ED (IIEF-EF score ≤18; model B), all the variables except age ≥40 years, BMI ≥30, and cannabis use were associated with ED. With multivariable logistic regression analysis, having a mining-related job (aOR, 2.5; 95% CI, 1.2-5.0; $P < .01$), work seniority >5 years (aOR, 2.1; 95% CI, 1.0-4.1; $P = .04$), alcohol consumption (aOR, 2.3; 95% CI, 1.1-4.8; $P = .03$),

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Table 3. Spearman correlations among age, IIEF-EF scores, sexual and thyroid hormones, and blood and urinary metal concentrations in miners.

	Age	IIEF-EF	SHBG	Total testosterone	Free testosterone	TSH	T4
Age		-0.14	0.44**	−0.02	−0.31**	−0.09	0.20
IIEF-EF			−0.21	−0.06	0.15	0.02	0.04
SHBG				0.49**	−0.19	−0.05	−0.06
Total testosterone					0.63**	−0.18	0.39
TSH							−0.07
Blood							
Mn	0.00	−0.05	0.14	0.14	0.05	0.19	−0.10
Co	−0.06	−0.08	0.07	−0.01	−0.15	−0.01	−0.17
Cd	0.03	−0.08	0.31**	0.07	−0.16	−0.16	−0.30**
Hg	−0.02	−0.02	−0.23*	0.03	0.24*	0.00	0.18
Pb	0.18*	−0.11	0.37**	0.09	−0.16	0.09	−0.29**
Urine[a]							
Li	−0.03	0.05	0.08	−0.02	0.02	0.06	0.04
Al	0.11	−0.14	0.03	0.08	−0.06	−0.10	0.10
Cr	0.01	−0.17	−0.07	0.05	0.13	0.01	0.17
Mn	−0.10	−0.11	−0.12	0.00	−0.03	−0.05	0.10
Co	−0.04	−0.16	0.22	0.05	−0.11	0.00	−0.17
Ni	0.28**	−0.16	0.33**	0.20	−0.17	−0.11	−0.11
Cu	0.01	−0.06	0.02	0.10	0.02	−0.07	−0.06
Zn	0.00	0.03	0.22	0.17	0.02	0.02	−0.13
As	0.01	−0.02	0.21	0.02	−0.08	0.16	−0.08
Se	−0.08	0.00	−0.09	−0.18	−0.20	0.03	−0.21
Mo	−0.10	0.07	−0.03	−0.10	−0.21	0.13	−0.10
Cd	0.10	−0.19*	0.23*	0.10	−0.12	−0.11	−0.24*
Sn	−0.08	−0.03	−0.10	0.08	0.20	−0.03	0.47**
Sb	−0.01	0.00	0.15	0.19	0.12	−0.03	−0.12
Ba	−0.08	−0.04	−0.05	0.13	0.10	−0.28*	0.01
Pb	0.07	−0.09	0.22*	0.18	0.05	−0.03	−0.02
U	0.01	−0.15	0.09	0.01	−0.19	0.11	−0.22

Abbreviations: IIEF-EF, International Index of Erectile Function–erectile function domain; SHBG, sex hormone–binding globulin; T4, thyroxin; TSH, thyroid-stimulating hormone. [a]Creatinine corrected. *$P < .05$ (2-tailed). **$P < .01$ (2-tailed).

Table 4. Logistic regression models testing the association between possible explanatory variables and ED among 138 miners and 139 bakers.

	Univariable			Multivariable		
	OR	95% CI	*P* value	aOR	95% CI	*P* value
Model A[a]						
Age ≥ 40 y	2.5	1.4-4.5	.001	1.6	0.8-3.2	.16
Body mass index ≥30	0.7	0.1-3.5	.66	0.7	0.1-5.0	.72
Tobacco smoking	1.8	1.0-3.1	.04	3.5	0.9-14	.07
Alcohol consumption	1.7	0.9-2.8	.06	1.6	0.7-3.5	.22
Tobacco + alcohol use	1.4	0.8-2.6	.24	0.3	0.1-1.4	.13
Cannabis use	1.3	0.5-3.7	.64	0.5	0.2-1.8	.28
Aphrodisiac use	3.5	2.1-6.0	<.001	2.6	1.5-4.8	.001
Mining-related job	4.3	2.5-7.4	<.001	3.1	1.7-5.6	<.001
Work seniority >5 y	1.8	1.1-3.0	.03	1.4	0.8-2.5	.26
Model B[b]						
Age ≥ 40 y	1.8	0.9-3.4	.07	1.0	0.5-2.2	.98
Body mass index ≥30	0.5	0.1-4.1	.52	0.5	0.0-5.1	.53
Tobacco smoking	2.2	1.2-4.1	.01	2.1	0.5-9.1	.33
Alcohol consumption	2.7	1.5-4.9	.001	2.8	1.2-6.7	.02
Tobacco + alcohol use	2.1	1.1-4.0	.02	0.4	0.1-2.5	.36
Cannabis use	1.7	0.6-5.0	.36	0.5	0.2-1.8	.30
Aphrodisiac use	5.2	2.8-9.5	<.001	4.2	2.2-8.0	<.001
Mining-related job	3.7	2.0-7.0	<.001	2.6	1.3-5.3	.01
Work seniority >5 y	2.3	1.3-4.2	.01	2.3	1.1-4.6	.02

Abbreviations: aOR, adjusted odds ratio; ED, erectile dysfunction; EF: Erectile function; IIEF-EF, International Index of Erectile Function–erectile function domain; OR, odds ratio. [a]Moedel A: any ED (IIEF-EF ≤24). [b]Model B: mild to moderate or moderate ED (IIEF-EF ≤18).

and aphrodisiacs use (aOR, 4.1; 95% CI, 2.1-7.83; $P < .001$) were significantly associated with mild to moderate ED (IIEF-EF score <18), after adjusting for age ≥40 years and tobacco smoking.

Mediation analysis

As shown by Figure 2, mediation analyses showed that the total effect (path *c*) of work seniority >5 years on erectile function was significant ($B = 0.83$, $P = .01$). The significant

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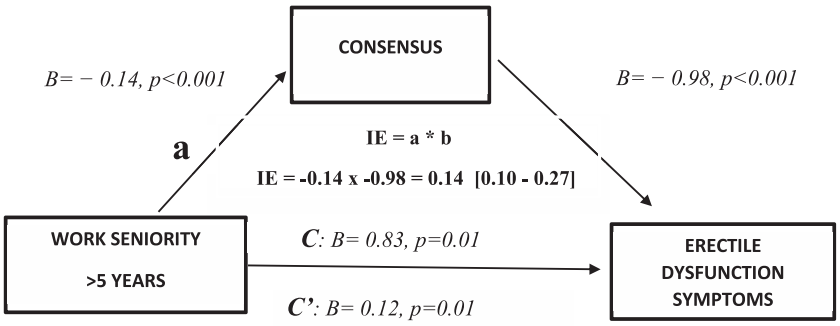

Figure 2. Mediation analysis: model including both groups. Schematic model of consensus as the mediator between work seniority >5 years and erectile dysfunction symptoms (Andrew Hayes's mediation model 4). *a*: Effect of work seniority >5 years on consensus. *b*: Effect of consensus on erectile dysfunction symptoms. *c*: Total effect of work seniority >5 years on erectile dysfunction symptoms. *c*′: Direct effect (DE): work seniority >5 years still predicts erectile dysfunction symptoms despite the presence of a mediator (consensus), partial mediation. $a \times b$: Indirect effect (IE) of work seniority >5 years on erectile dysfunction symptoms.

coefficients of path *a* ($B = -0.14$, $P < .001$) and path *b* ($B = -0.98$, $P < .001$) indicated negative associations of work seniority >5 years on consensus between partners (path *a*) and consensus between partners on erectile function (path *b*). In addition, the point estimate (0.14; bias-corrected bootstrap 95% CI, 0.10-0.27) of the indirect effect (path $a \times b$) between work seniority >5 years and ED symptoms through consensus indicated that the indirect effect of work seniority >5 years on erectile function was statistically significant. In addition, the direct effect of work seniority >5 years on erectile function (path *c*′) was significant ($B = 0.12$, $P = .01$), indicating that consensus between partners partially mediated the relationship between work seniority >5 years and self-reported ED.

Discussion

This cross-sectional study was designed to explore widely expressed concerns about the occurrence of ED associated with work in mining in the Katanga province. In a preliminary study,[13] we found an association between ED and having a mining-related job. In the present study, we confirmed this association and investigated possible associations with personal characteristics, marital consensus, sex hormones, and trace metals in blood and urine. To our knowledge, this is the first study to investigate ED among mine workers not only in Katanga but elsewhere.

Overall, we confirmed that self-reported ED was twice as prevalent among miners as compared with a socioeconomically and reasonably well-matched control group of bakers. The high prevalence of ED in these relatively young men cannot be attributed to diabetes, hypertension (or atherosclerosis), obesity, or low testosterone levels. Although the miners were, as expected, highly exposed to various trace metals, we found little evidence for a direct association between ED and specific trace metals in blood or urine. However, lifestyle factors (especially alcohol use) and a long history of work in mining far from home may be responsible for disagreement between partners on matters of importance to marital relationships and, hence, poor sexual function among miners. The widespread use of locally made plant-based aphrodisiacs (ie, locally made beverages from plants known to have aphrodisiac properties) merits more scientific attention.

Before discussing these results, we wish to mention the strengths and limitations of our study. The strengths include (1) its originality as the first epidemiologic study of ED among a large group of miners as compared with a suitable control group, (2) the use of validated questionnaires to assess erectile function and marital relation quality, (3) the measurements of hormones (sexual and thyroid), and (4) the characterization of trace metal exposure by blood and urinary biomonitoring. Nevertheless, we also acknowledge several limitations. First, ED was defined by questionnaire only, without documentation by objective means such as nocturnal penile rigidity measurements or Doppler testing. However, the latter procedures are not available in our medically underserved area, and they would not have been feasible in an epidemiologic study of >200 participants. Nevertheless, in the future, we intend to develop more advanced clinical diagnostic investigations for selected patients with complaints of ED in our region. Second, participants were enrolled via convenience sampling, which could lead to selection biases. Yet, we have no reasons to believe that participation was influenced by the sensitive nature of the study or by the presence or absence of ED complaints. Third, our study did not objectively exclude the presence of underlying conditions, such as diabetes or atherosclerotic disease, but a major role of these diseases can be confidently excluded in view of the young age of this population doing physically hard work.

In this study, the prevalence of self-reported ED among miners <40 years old was 9-fold higher than the prevalence in participants of the same age range from the general population in the United States.[23] ED has long been considered an age-dependent disease, with most men developing symptoms of ED from 40 years of age.[24] Age is known to be the most common risk factor for ED, and the correlation between age >40 years and ED is attributed to declines in testosterone levels and to veno-occlusive dysfunction that increases collagen deposition in the corpora cavernosa with a loss of corporal smooth muscle cells.[25] However, recent studies in industrially developed countries have shown a growing incidence of ED in men <40 years old,[3] but whether this trend has any relation with our findings is unclear and even doubtful.

We found lower scores on all 5 domains of the IIEF in miners vs bakers. This finding could be partially explained by the poorer quality of marital relations among miners, as revealed through the RDAS showing that almost all miners (97%) reported relational distress to some degree, as opposed to only 23% among bakers. Poorer marital relationship may contribute to ED.[26] Clinical experience suggests that when partners are dissatisfied with their sexual relationship or

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are experiencing difficulties such as ED, they tend to be less satisfied with their overall relationship.[27] Physical or mental stress experienced at work could also be a factor affecting erectile function in miners, whose work is physically demanding and who often spend long periods away from home for their work.[28] In an unpublished study, we found that a high proportion of mine workers experienced decreases in oxygen saturation (as assessed by pulse oximetry) during underground work, probably as a result of insufficient ventilation of the mines. We hypothesize that chronic hypoxia at work could explain negative impacts on cardiovascular health[29] and consequently on the erectile function of some young mine workers.

Regarding sexual hormones, our findings showed somewhat higher SHBG and lower free testosterone levels in miners than bakers. These results could be explained by the slightly older age of the miners.[30] Interestingly, we found a positive correlation between SHGB and age and an inverse correlation between free testosterone and age. The latter result is consistent with previous studies showing that serum total and free testosterone levels in men reach a peak in the second and third decades of life and then decline gradually with advancing age.[31]

Among participants aged <40 years, regular alcohol and aphrodisiacs consumption was associated with ED. The association between chronic alcohol consumption and ED has been reported by a number of studies,[2,32,33] with an estimated prevalence of 72% among alcoholic men,[34] and the possible mechanism could be the alteration of corpus cavernosum by ethanol.[32]

Regarding aphrodisiacs consumption, at this stage, we do not know whether this factor is a cause or a consequence of ED in our study. ED can be managed with plants that contain bioactive compounds influencing erection.[35] Plants may also cause toxic effects when they are taken chronically.[36] This topic is currently being investigated.

As expected, most trace metals were higher in the blood and urine of miners vs bakers. We also found that, among miners, SHBG correlated significantly with blood Pb, blood Cd, and urinary Cd. This result is consistent with studies finding an association between ED and Pb[37,38] and Cd,[12,39] possibly because Pb and Cd can deregulate the hypothalamic-pituitary-adrenal axis. Decreased testosterone levels have been shown in infertile men with documented occupational metal exposure.[40] Some trace elements, such as Cd, As, and Pb, are capable to disrupt the neuroendocrine system, triggering hormonal imbalances by blocking the secretion of androgens from Leydig cells or inhibin B from Sertoli cells.[41] Likewise, a suppressive influence of arsenic on testosterone release has been reported in a rat model.[42] Our findings suggest that further studies are needed to explore the disrupting role of trace metals on sex hormones.

The current study found a partially mediating role of disagreement within the partner relationship in the association between work seniority >5 years and ED symptoms. Work seniority >5 years was directly associated with ED symptoms; yet, work seniority >5 years was negatively correlated to consensus in the partner relation, which was inversely related to the score for erectile function. Our results are consistent with a study that supports the contribution of relationship difficulties to erectile difficulties.[26] Clinical evidence supports that relationship difficulties contribute to erectile problems.[27] The IIEF Swahili and the Revised Dyadic Adjustment Scale Swahili are intended as Appendix. Kindly add appendix file before references.

Conclusion

Within the limits of a cross-sectional epidemiologic study and in the absence of serious methodological biases, we are confident that our study provides compelling evidence for increased ED among mine workers in Katanga province. The findings support the pursuit of similar studies elsewhere in the world.

In summary, our findings indicate that, as compared with controls, male miners in Katanga report poorer sexual function and poorer marital relationships, and they have somewhat lower free testosterone levels. The latter may be due to their high exposure to trace metals (especially Pb, Cd, and As), but we found no evidence that ED was related to the degree of internal metal exposure, as assessed by biomonitoring. ED was associated with lower quality of the marital relationship, possibly due to long time spent away from home in mining. We speculate that the arduous nature of artisanal mining work may also contribute to ED, but further studies are needed to unravel possible physiologic mechanisms with psychological and relational etiologic factors leading to ED in artisanal mine workers.

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Author contributions

P.M.O., C.B.L.N., P.E., and B.N.: conception, methodology. C.B.L.N.: supervision of the field work and writing–review and editing. P.M.O., J.P.K., T.C.K., GKI and T.K.-K.: investigations. J.B.: supervision of hormone measurements. V.H.: supervision of metal measurements. P.M.O. and B.N.: data curation and formal analysis. P.M.O.: writing original draft under supervision of P.E. and B.N. B.N., P.E., J.P.K., T.C.K., and T.K.-K., GKI: writing–review and editing. L.R. and A.M.M.: funding acquisition, project administration, and writing-review.

Supplementary material

Supplementary material is available at *Sexual Medicine* online.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Data availability

The data that support the findings of this study are available on reasonable request from the corresponding author.

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Appendix

International Index for Erectile Function (Swahili translation). Maswali Matano ya kwanza yanahusu usimamaji wa uume.

Q1. Kwa mwezi mmoja uliopita, ni kwa mara ngapi umeweza kusimamisha uume wakati wakujamiana?

1) Sijafanya tendo la kujamiana kwa mwezi uliopita
2) kwa nadra sana/hakuna
3) Aghalabu/Mara chache sana (chini ya nusu ya nyakati nilizo fanya tendo)
4) Mara chache karibu nusu ya nyakati nilizo fanya tendo
5) Zaidi ya nusu ya nyakati nilizo fanya tendo
6) karibu kila wakati/kila wakati

Q2. Kwa mwezi mmoja uliopita, wakati uume umesimama kabla ya tendo, Je uume wako ulisimama vya kutosha kuweza kuuingiza ukeni?

1) Sijafanya tendo la kujamiana kwa mwezi uliopita
2) kwa nadra sana/hakuna
3) Aghalabu/Mara chache sana (chini ya nusu ya nyakati nilizo fanya tendo)
4) Mara chache karibu nusu ya nyakati nilizo fanya tendo
5) Zaidi ya nusu ya nyakati nilizo fanya tendo
6) karibu kila wakati/kila wakati

Q3. Kwa mwezi mmoja uliopita,wakati unataka kufanya tendo, nimara ngapi uliweza kuingiza uume ukeni?

1) Sijafanya tendo la kujamiana kwa mwezi uliopita
2) Kwa nadra sana/hakuna
3) Aghalabu/Mara chache sana (chini ya nusu ya nyakati nilizofanya tendo)
4) Mara chache karibunusuyanyakatinilizofanyatendo
5) Zaidi ya nusu ya nyakati nilizofanya tendo
6) Karibu Kila wakati/kila wakati

Q4. Kwa mwezi mmoja uliopita, wakati wa tendo, ni mara ngapi uliweza kufanya tendo bila uume kulala baada ya kuuingiza ukeni?

1) Sija fanya tendo la kujamiana kwa mwezi uliopita
2) kwa nadra sana/hakuna
3) Aghalabu/Mara chache sana (chini ya nusu ya nyakati nilizo fanya tendo)
4) Mara chache karibu nusu ya nyakati nilizo fany0a tendo
5) Zaidi ya nusu ya nyakati nilizo fanya tendo
6) karibu kila wakati/kila wakati

Q5. Kwa mwezi mmoja uliopita,wakati watendo,ni kwa kiasi gani ilikua ngumu kufanya tendo bila uume kulala kabla yaku maliza kujamiana?

1) Sijafanya tendo la kujiamiana kwa mwezi uliopita
2) Ngumu iliyo pitiliza
3) Ngumu sana
4) Ngumu
5) Ngumu kidogo
6) Siongumu

Q6. Ume jiamiana mara ngapi kwa mwezi uliopita?

1) Sijafanya tendo mwezi uliopita
2) mara 1-2
3) mara 3-4
4) mara 5-6
5) mara 7-10
6) mara 11-20

Q7. Kwa mwezi uliopita, ni mara ngapi umeridhishwa na tendo wakati wa kujamiana?

1) Sija fanya tendo la kujamiana kwa mwezi uliopita
2) kwa nadra sana/hakuna
3) Aghalabu/Mara chache sana (chini ya nusu ya nyakati nilizo fanya tendo)
4) Mara chache karibu nusu ya nyakati nilizo fanya tendo
5) Zaidi ya nusu ya nyakati nilizo fanya tendo
6) karibu kila wakati/kila wakati

Q8. Kwa mwezi uliopita, ni kwa kiasi gani umeridhishwa na tendo wakati waku jamiana?

1) Sija fanya tendo mwezi uliopita
2) Sija furahia kabisa tendo
3) Sija furahia sana
4) Nime furaia kwakiasi
5) Nime furahia sana
6) Nime furahia maradufu

Maswali mawili yafuatayo yanarejea ufikaji wakileleni wakati wa tendo/kujamiana.

Q9. Kwa mwezi uliopita, uli mwaga shahawa mara ngapi wakujamiana?

1) Sija fanya tendo mwezi uliopita
2) Sija furahia kabisa tendo
3) Sija furahia sana
4) Nime furaia kwakiasi
5) Nime furahia sana
6) Nime furahia maradufu

Q10. Kwa mwezi uliopita,wakati unafanya tendo, ni mara ngapi umehisi kua kileleni aidha kwa kumwaga shahawa/bila kumwaga shahawa?

1) Sija fanya tendo mwezi uliopita
2) Sija furahia kabisa tendo
3) Sija furahia sana
4) Nime furaia kwakiasi
5) Nime furahia sana
6) Nime furahia maradufu

Maswali mawili yafuatayo yanauliza kuhusu hamu ya tendo. Kwa muktadhahuu, Hamu ya tendo inaweza kufafanuliwa kama hisiaya kutaka kujamiana(Kwamfano kufanya punyeto au kujamiana), ku waza juu ya tendo,au kuchanganyikiwa kwa kukosa tendo.

Q11. Kwa mwezi uliopita, ni mara ngapi umekua na hamu ya kujamiana?

1) Sija fanya tendo la kujamiana kwa mwezi uliopita
2) kwa nadra sana/hakuna
3) Aghalabu/Mara chache sana (chini ya nusu ya nyakati nilizo fanya tendo)
4) Mara chache karibu nusu ya nyakati nilizo fanya tendo
5) Zaidi ya nusu ya nyakati nilizo fanya tendo
6) karibu kila wakati/kila wakati

Q12. Kwa mwezi uliopita, hamu yako ya kutaka tendo ilikuya kiwango gani?

1) Chini sana/haipo
2) Chini
3) Kiasi/Kawahida
4) Juu
5) Juu sana

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Maswali mawili yafuatayo yanarejea uridhishwaji wa tendo.

Q13. Kwa mwezi uliopita, ni kwa kiasi gani umeridhishwa na tendo la kujamiana/maisha yako ya ngono?

1) Sijaridhishwa kabisa
2) Sijaridhishwa kwa wastani
3) Nime ridhishwa kidogo
4) Nime ridhishwa wastani
5) Nime ridishwa sana

Q14. Kwa mwezi uliopita, nikwa kiasi gani umeridhishwa na tendo la kujamiana/maisha yako ya ngono na mwenza wako?

1) Sijaridhishwa kabisa
2) Sijaridhishwa kwa wastani
3) Nime ridhishwa kidogo
4) Nime ridhishwa wastani
5) Nime ridishwa sana

Swali la mwisho linarejea usimamaji wa uume.

Q15. Kwa mwezi uliopita, ni kwa kiasi gani unajiama ini kwamba unaweza kupata na kudindisha uume wako?

1) Kiwango cha Chini sana
2) Kiwango cha Chini
3) Kwa Kiasi fulani
4) Kiwango cha juu
5) Kiwango cha juu sana

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Revised Adjustment Scale (Swahili translation)

Watu wengi wana kutoelewana katika mahusiano yao. Tafadhali onyesha chini ya makadirio ya kiwango cha makubaliano au kutokubaliana kati yako na mshirika wako kwa kila kitendo kwenye orodha ifuatayo.

		Kila siku tuna kubaiana	*Mara zote tuna kubaliana*	*Mara chache tuna kubaliania*	*Mara nyingi haut kubaliani*	*Mara zote haut kubaliani*	*Kila siku haut kubaliani*
1	Mambo ya kidini na Imani	*5*	*4*	*3*	*2*	*1*	*0*
2	Namna ya kuonyeshana mapenzi/upendo	*5*	*4*	*3*	*2*	*1*	*0*
3	Kufanya maamuzi makubwa	*5*	*4*	*3*	*2*	*1*	*0*
4	Namna ya kufanya mapenzi	*5*	*4*	*3*	*2*	*1*	*0*
5	Juu ya jambo gani ni Jema au zuri kufanywa	*5*	*4*	*3*	*2*	*1*	*0*
6	Maamuzi ya kazi/ajira	*5*	*4*	*3*	*2*	*1*	*0*
		Kila wakati	*Wakati mwingi*	*Mara nyingi*	*Mara chache sana*	*Kwa nadra sana*	*Haijawahi kutokea*
7	Ni mara ngapi umejadiliana au kufikiria talaka, kutengana au kumaliza uhusiano wako na mweza wako	*0*	*1*	*2*	*3*	*4*	*5*
8	Ni mara ngapi wewe na mweza wako mnagombana?	*0*	*1*	*2*	*3*	*4*	*5*
9	Je ushawahi kujuta kufungwa ndoa (au kuishi Pamoja na mweza wako)?	*0*	*1*	*2*	*3*	*4*	*5*
10	Ni mara ngapi wewe na mwezi wako“Mnakasirikiana”?	*0*	*1*	*2*	*3*	*4*	*5*
11	Je, wewe na mwenzi wako huwa mnatoka na kufanya mambo mbalimbali pamoja	*0*	*1*	*2*	*3*	*4*	*5*
	Je, ni mara ngapi unaweza kusema matukio yafuatayo yanatokea kati yako na mwenzi wako?						
		Haijawahi kutokea	*Inaweza isitokee hata mora moja kwa mwezi*	*Mara moja au mbili kwa mwezi*	*Mara moja au mbili kwa wiki*	*Mara moja au mbili kwa siku*	*Mara nyingi tu*
12	Mnabadilishana mawazo	*0*	*1*	*2*	*3*	*4*	*5*
13	Mnafanya jabo la maendeleo pamoja	*0*	*1*	*2*	*3*	*4*	*5*
14	Mnajadiliana vitu kwa utulivu	*0*	*1*	*2*	*3*	*4*	*5*

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