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Effectiveness of a parent-based intervention to improve adolescents' sexual and reproductive health knowledge: a pilot study

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Abstract

Objectives: Adolescents continue to demonstrate uneven sexual and reproductive health (SRH) knowledge, particularly in applied domains such as contraception, gender identity, and digital safety. While school-based education emphasizes biological aspects of reproduction, structured family-based SRH education remains limited. This study examined whether empowering parents with structured, culturally sensitive SRH content and professional guidance may improve adolescents' SRH knowledge through parent–adolescent communication on sexual issues (PACS).

Methods: A quasi-experimental single-arm pre–post pilot study was conducted among Malaysian parent–adolescent dyads. Parents received a six-week structured SRH module delivered via a website, supported by healthcare professionals through digital platforms, and engaged in PACS. Adolescents completed a validated 30-item SRH knowledge questionnaire at baseline and post-intervention.

Results: Fifty adolescents with a mean age of 14.45 (SD=1.50) years completed the study (completion rate: 89.3 %). Median knowledge scores increased significantly from 19.0 (IQR=11.5–26.5) to 23.0 (IQR=17–29) ($p<0.001$, $r=0.62$). Significant improvements were observed across several knowledge domains, including contraception misconceptions, oral sex and pregnancy risk, gender identity, digital safety, grooming awareness, and abortion ($r=0.28–0.40$, $p<0.05$).

Conclusions: This pilot study provides preliminary evidence that empowering parents with digitally delivered, structured SRH education and professional support can enhance parent–adolescent communication and improve adolescents' knowledge, particularly in sensitive and under-addressed domains. This family-based approach offers a feasible and scalable complement to school-based SRH education, especially in culturally sensitive and resource-limited settings.

Keywords: sexual health; family communication; adolescent health; parents; telemedicine

Introduction

Adolescent sexual and reproductive health (SRH) remains a global public health priority, with persistent gaps in knowledge and ongoing engagement in risk behaviours reported across diverse settings [1]. While many countries have implemented school-based SRH education, the scope, depth, and acceptability of such programmes vary considerably, particularly in culturally sensitive contexts where topics such as contraception, digital sexual risks, and gender identity may be inconsistently addressed [2–4]. These challenges are not unique to any single country but are widely observed across low- and middle-income countries as well as in more conservative communities within high-income settings.

In Malaysia, national data reflect similar concerns, with adolescents demonstrating ongoing risky sexual behaviours alongside gaps in applied SRH knowledge [2]. This context is broadly representative of many multicultural and value-sensitive societies, where formal curricula often emphasize biological aspects of reproduction while more complex psychosocial dimensions remain under-addressed.

Parent–adolescent communication on sexual issues (PACS) has been associated with improved adolescent SRH knowledge and safer behavioural intentions [5, 6]. However, effective PACS depends not merely on parental willingness

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but also on parental competence, confidence, and access to structured guidance [7]. In culturally sensitive settings, parents may wish to educate their adolescents but feel constrained by limited knowledge, discomfort with sensitive topics, and uncertainty about appropriate communication approaches [7–9].

While existing literature has primarily examined PACS as a predictor of adolescent outcomes, there remains a relative paucity of research on interventions that actively empower parents as primary educators in SRH. This gap is particularly evident in culturally sensitive settings, where family-based approaches may be more feasible and potentially more effective than exclusively school-based models. In addition, interventional evidence from low- and middle-income countries remains limited, with few studies from Iran, Thailand, Taiwan and selected African settings [10–12]. Providing parents with evidence-based modules and professional support may transform them from passive observers into active health educators. This study, therefore, conceptualizes PACS not as spontaneous discussion but as a structured, parent-mediated educational strategy.

This study is grounded in Empowerment Theory, which posits that increasing individuals' knowledge and perceived competence enhances engagement in behavioural action [13]. Psychological empowerment encompasses interactional (knowledge acquisition), intrapersonal (self-efficacy), and behavioural (participatory action) components. In the context of SRH education, equipping parents with structured content and professional guidance may strengthen their knowledge and communication self-efficacy, thereby enhancing effective PACS.

The study is further informed by Ecological Systems Theory [14], which conceptualizes adolescent development as occurring within interconnected environmental systems. The family represents the most immediate microsystem shaping adolescents' norms and health beliefs. In contexts where school-based SRH education may be limited by sociocultural constraints, empowering the family microsystem provides a proximal and culturally congruent pathway for knowledge transmission. Incorporating health literacy strategies within the family environment can further support meaningful health-related communication and encourage shared healthy behaviours [15], which may contribute to delaying sexual initiation and preventing unsafe sexual practices among adolescents [16]. Healthcare professionals operate within the mesosystem, bridging institutional knowledge and the home environment. This aligns with evidence that parents require comprehensive, multi-domain education and context-sensitive support to communicate effectively with their adolescents about reproductive and sexual health [17].

The conceptual framework guiding this study is illustrated in Figure 1. It proposes that professional support enhances parental knowledge and self-efficacy, which in turn facilitates structured PACS and improves adolescent SRH knowledge. Therefore, this study aimed to examine whether empowering parents with structured SRH content and professional support improves adolescents' SRH knowledge through enhanced PACS.

Materials and methods

Study design and participants

Given the sociocultural sensitivities surrounding SRH in Malaysia, a pilot study was initiated to evaluate the feasibility and preliminary impact of a parent-mediated intervention. Thus, a quasi-experimental single-arm pre–post design was conducted between February and March 2025 in Malaysia. Adolescents and their parents were recruited using convenience and snowball sampling strategies. Although adolescence is defined by the World Health Organization as the period between 10 and 19 years of age [18], the present study targeted adolescents aged 13–17 years. This age group comprises the majority of Malaysian secondary school students and represents a critical developmental stage during which cognitive maturity, identity formation, autonomy, and interpersonal relationships become increasingly prominent [19]. Accordingly, this age group was considered appropriate for evaluating a parent-mediated SRH intervention.

Initial recruitment was conducted through institutional collaboration with a secondary school, followed by dissemination through professional and personal networks via messaging platforms. Inclusion criteria required adolescents to be Malaysian citizens, able to understand Malay language, have access to online platforms, stay with parents, and have their parents agree to be involved in the intervention. Adolescents with reported cognitive or communication difficulties were excluded. The minimum required sample size was 40 dyads, calculated using G*Power for a paired comparison design, assuming a medium effect size ($d=0.50$), $\alpha=0.05$, and 80 % power.

Intervention

The intervention was delivered online, enabling participation from families across different regions. Parents participated in a six-week structured SRH module delivered via a dedicated Google website platform. The module comprised six chapters: (1) puberty and anatomy, (2) relationships and

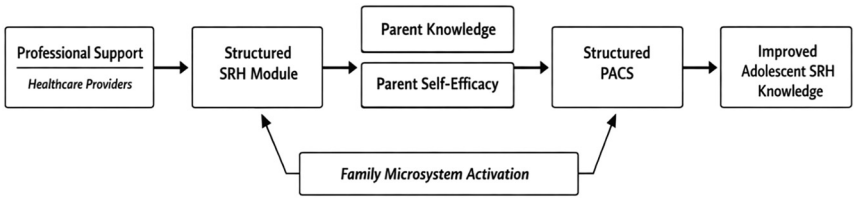


Figure 1: Conceptual model of structured parent empowerment and adolescent SRH knowledge.

appropriate touch, (3) sexuality, (4) reproductive health, (5) cyber safety, and (6) child protection. Each week, parents accessed structured educational materials, including short video presentations (approximately 10–15 min) and downloadable resources. Parents were then encouraged to engage in PACS by applying the content through guided discussions with their adolescents.

For example, in the "relationships and appropriate touch" chapter, parents were guided to discuss concepts of healthy and unhealthy relationships, safe and unsafe touch, and appropriate steps to take if adolescents encounter potentially harmful situations. Parents were encouraged to apply positive communication techniques, such as creating a comfortable and respectful environment, using age-appropriate and culturally sensitive language, providing non-judgmental responses, and incorporating positive reinforcement. Parents were also guided to actively listen, express their views clearly while allowing adolescents to share opinions or ask questions, and model mutual respect, including the ability to apologise and forgive. Adolescents were supported in making decisions aligned with sociocultural and religious values. Where knowledge gaps existed, parents and adolescents were encouraged to seek information together from reliable sources. In addition, parents were prompted to use open-ended questioning techniques to facilitate adolescent engagement and reflective discussion. The estimated duration for weekly parent engagement, including content review and discussion with adolescents, was approximately 20–30 min.

Professional support was provided by two researchers who are Family Medicine Specialist trainees, recognising that parents often require guidance to communicate effectively with their adolescents about risk-taking behaviours [20]. This support followed a structured format: (1) Synchronous Briefing: At Week 1, parents attended a one-hour live briefing via Google Meet. This session introduced the module and provided a dedicated forum for healthcare professionals to address parental inquiries and concerns before embarking on the intervention. (2) Asynchronous Support: Parents received weekly reminders and guidance via a dedicated WhatsApp group. These reminders were synchronized with the release of new educational materials to facilitate the consistent implementation of PACS. This dual-layered professional support aimed to enhance parental technical knowledge, communication self-efficacy, and confidence in navigating sensitive SRH topics within the home environment.

Outcome measure

Adolescents' SRH knowledge was assessed using the 30-item Knowledge on Sexual and Reproductive Health Questionnaire (KSRH-Q), developed based on the intervention content. Items were scored dichotomously (correct=1, incorrect/not sure=0), yielding a total score range of 0–30. Content validity was established through expert review, and pilot testing confirmed clarity and comprehensibility among adolescents. The instrument demonstrated acceptable internal consistency with Cronbach's α of 0.79. The questionnaire was administered at baseline (week 0) and immediately after the six-week intervention (week 6).

Statistical analysis

Data were analysed using IBM SPSS Statistics (Version 29). Descriptive statistics summarized participant characteristics and baseline knowledge patterns. As knowledge scores were not normally distributed (Shapiro–Wilk $p<0.05$), changes in total knowledge scores were assessed using the Wilcoxon signed-rank test. The Wilcoxon test statistic (W) and corresponding p-values were reported. Item-level changes in paired categorical responses were analysed using McNemar's test. Statistical significance was set at $p<0.05$.

Ethical consideration

This study was conducted in accordance with the ethical principles outlined in the World Medical Association Declaration of Helsinki and received approval from the University Institutional Research and Ethical Committee. This study was supported by a university-based research grant (Reference No: JEP-2024-684). Written informed consent was obtained from all parents, and assent was obtained from participating adolescents prior to data collection.

Results

A total of 56 parent–adolescent dyads completed baseline assessment. Of these, 50 dyads completed the six-week intervention and post-intervention assessment, yielding a completion rate of 89.3 %. The final analysed sample (n=50) exceeded the minimum sample size required for this pilot investigation to detect initial efficacy and evaluate recruitment strategies for future large-scale trials.

The mean age of parents was 43.07 (SD=4.58) years. Most participating parents were mothers (94.6 %), Malay (96.4 %), and Muslim (98.2 %), with a majority having attained tertiary education (78.6 %). As shown in Table 1, the mean age of adolescents was 14.45 (SD=1.50) years, and they were predominantly females (67.9 %). The sociodemographic profile suggests a relatively homogenous sample drawn largely from Malay (96.4 %) and Muslim (98.2 %) families with stable educational and employment backgrounds.

The six dyads who did not complete the intervention were demographically comparable to those who completed the study, with no notable differences in ethnicity, parental education, or socioeconomic indicators.

Knowledge patterns pre-post intervention

As shown in Table 2, after receiving SRH education from their parents and performing regular PACS over six weeks, the adolescents' median knowledge scores increased significantly from 19.0 (IQR=11.5–26.5) to 23.0 (IQR=17–29) ($p<0.001$), representing a large effect size (r=0.62).

Significant improvements were observed in 10 knowledge items following the intervention, with effect sizes ranging from small to medium (r=0.28 to 0.40) (Table 3). These items largely clustered within three areas: correction of misconceptions, risk and preventive understanding, and sensitive socio-cultural concepts. The most robust improvements (medium effect sizes) were noted in the correction of misconceptions regarding the age of menarche (r=0.40, p=0.004) and abortion medication safety (r=0.40, p=0.004). Significant gains were also observed in addressing misunderstandings of oral sex and pregnancy risk (r=0.37, p=0.008) and STI prevention (r=0.32, p=0.022). Improvements in practical risk-related knowledge included internet usage limits (r=0.35, p=0.012), awareness of unplanned pregnancy consequences (r=0.32, p=0.022), and grooming recognition (r=0.28, p=0.039). Notably, medium effect sizes were achieved in clarifying concepts of gender identity (r=0.38, p=0.007), sex assigned at birth (r=0.35, p=0.012), and understanding of responsible partner selection (r=0.28, p=0.039) In contrast, items assessing basic puberty and anatomical knowledge showed negligible change (r=0.00), likely reflecting a high ceiling effect due to high baseline correct responses rates (94 %–100 %).

Table 1: Sociodemographic characteristics of adolescents at baseline (n=56).

Variable	n (%) or mean (SD)
Age, years	14.45 (1.50)
Gender	
Female	38 (67.9)
Male	18 (32.1)
Ethnicity	
Malay	54 (96.4)
Non-Malay	2 (3.6)
Religion	
Islam	55 (98.2)
Christian	1 (1.8)
Mother's occupation	
Government sector	40 (71.4)
Private sector	7 (12.5)
Unemployed	9 (16.1)
Father's occupation	
Government sector	25 (44.6)
Private sector	18 (32.1)
Self-employed	13 (23.2)

Discussion

This study provides preliminary evidence that a structured, parent-mediated sexual and reproductive health (SRH) intervention was associated with significant improvements in adolescents' overall SRH knowledge. The high completion rate (89.3 %) highlights the feasibility and cultural acceptability of this parent-mediated intervention within a culturally sensitive context. This retention level is particularly notable given the sensitive nature of the SRH topics discussed. The strategic use of low-cost, ubiquitous social media platforms like WhatsApp served as a critical tool for maintaining engagement. By providing weekly asynchronous guidance and reminders through a familiar interface, the intervention reduced the participation burden on parents, thereby enhancing their persistence and self-efficacy over the six weeks. While this high engagement was observed primarily among families with relatively stable educational and socioeconomic backgrounds, these findings highlight the potential of leveraging existing digital ecosystems to bridge gaps between professional healthcare guidance and home-based education across diverse settings. This is consistent with growing evidence that digital interventions demonstrate promising impacts in enhancing adolescents' knowledge and reducing sexual risk behaviours [21].

Table 2: Changes in adolescents' SRH knowledge scores pre-post intervention (n=50).

Measure	Pre-intervention median (IQR)	Post-intervention median (IQR)	W	Z	p-Value	Effect size, r
SRH knowledge score	19.0 (11.5–26.5)	23.0 (17.0–29.0)	690.5	−4.38	<0.001	0.62

Effect size values of 0.1, 0.3, and 0.5 denote small, medium, and large effects, respectively.

Table 3: Item-level changes in adolescent SRH knowledge (n=50) .

Item	Pre- intervention correct, %	Post-intervention correct, %	McNemar's χ^2	Z	p-Value	Effect size, r
1. Baby grows in the uterus	98	100	0.00	0.00	1.000	0.00
2. Menstrual blood origin	94	98	0.00	0.00	1.000	0.00
3. Voice change puberty	100	100	0.00	0.00	1.000	0.00
4. Menstruation as puberty	98	100	0.00	0.00	1.000	0.00
5. Acne as a puberty sign	98	100	0.00	0.00	1.000	0.00
6. Oral sex & pregnancy risk	68	70	7.00	**2.65**	**0.008**	**0.37**
7. STIs prevention misconception	26	36	5.00	**2.24**	**0.022**	**0.32**
8. Menarche age misconception	56	80	8.10	**2.85**	**0.004**	**0.40**
9. Online stranger safety	94	96	1.00	1.00	0.500	0.14
10. Unsafe relationship fear	82	92	2.00	1.41	0.125	0.20
11. Sex assigned at birth	90	96	6.00	**2.45**	**0.012**	**0.35**
12. Gender identity definition	30	46	7.30	**2.70**	**0.007**	**0.38**
13. Equal expression rights	64	68	2.00	1.41	0.157	0.20
14. Homosexual STI risk	80	88	2.00	1.41	0.250	0.20
15. Right to choose a partner	86	90	4.00	**2.00**	**0.039**	**0.28**
16. A condom prevents pregnancy	78	92	3.00	1.73	0.125	0.24
17. Safe sex in marriage	86	94	2.00	1.41	0.125	0.20
18. HIV transmission knowledge	82	88	2.00	1.41	0.500	0.20
19. Irregular periods & pregnancy	50	68	3.00	1.73	0.083	0.24
20. Unplanned pregnancy risk	58	76	5.00	**2.24**	**0.022**	**0.32**
21. Internet exposure risk	88	90	1.00	1.00	0.500	0.14
22. Internet use limit	54	66	6.00	**2.45**	**0.012**	**0.35**
23. Parental password access	30	40	3.00	1.73	0.083	0.24
24. Multimedia act protection	76	84	3.00	1.73	0.250	0.24
25. Child pornography penalty	94	96	1.00	1.00	1.000	0.14
26. Grooming definition	82	90	4.00	**2.00**	**0.039**	**0.28**
27. Lewd comments offense	92	94	2.00	1.41	0.500	0.20
28. Statutory rape definition	88	92	2.00	1.41	0.250	0.20
29. Seek help for gender concerns	74	82	3.00	1.73	0.125	0.24
30. Abortion pill safety misconception	62	72	8.10	**2.85**	**0.004**	**0.40**

Effect size values of 0.1, 0.3, and 0.5 denote small, medium, and large effects, respectively. Bold values indicate statistically significant pre–post improvements ($p<0.05$). Effect size values of 0.1, 0.3, and 0.5 denote small, medium, and large effects, respectively.

The significant increase in adolescents' knowledge scores with a large effect size following six weeks of structured parent–adolescent communication on sexual issues (PACS) suggests that the intervention was not merely informational but functioned through an interactive, relational mechanism. This aligns with prior evidence demonstrating the positive association between PACS and adolescent SRH outcomes [5, 6]. Significant gains were observed in three thematic areas: correcting misconceptions, strengthening risk and preventive literacy, and clarifying sensitive sociocultural concepts.

Firstly, several improvements were reflected in the correction of misconceptions. Previous Malaysian studies have highlighted gaps in adolescents' understanding of contraception and reproductive health risks [3, 4]. The present findings suggest that structured parental guidance may effectively address inaccurate beliefs that could otherwise contribute to risky behaviours. The intervention had managed to correct the misunderstandings about contraceptive pills, preventing sexually transmitted infections, oral sex, and pregnancy risk, age of menarche, and abortion medication safety, highlighting the role of parents as credible and contextually relevant sources of information.

Secondly, improvements were observed in items related to risk and preventive understanding, such as recognizing internet grooming, recommended internet usage limits, and

awareness of adverse outcomes associated with unplanned pregnancy. These domains reflect real-world risk exposure in both digital and relational contexts. The reinforcement of preventive literacy within the family environment is supported by literature demonstrating that active parental engagement is associated with improved protective knowledge and health-promoting behaviours in adolescents [7, 22].

Thirdly, significant changes were observed in items addressing sensitive socio-cultural concepts, including differentiation between sex assigned at birth, gender-related constructs, and responsible partner selection. The improvement in understanding sex assigned at birth suggests enhanced differentiation between biological sex characteristics and broader gender-related concepts. In the Malaysian context, where discussions surrounding sex and gender may be socially sensitive, structured parent-mediated communication may offer a safer and culturally appropriate platform for clarifying foundational distinctions and thus, supporting a clearer understanding of gender-related concepts within culturally appropriate frameworks. Similarly, improvement in the item assessing responsible partner selection reflects a strengthened understanding of healthy long-term relationship values. In this study, positive sexuality was framed within culturally appropriate norms, emphasizing responsible and thoughtful selection of a life partner rather than permissive sexual behaviour. Such topics are often minimally addressed in formal curricula due to sociocultural sensitivities [23]. The observed improvements, therefore, suggest that structured family-based discussions can facilitate clarification of complex and sensitive concepts while remaining aligned with prevailing societal values. This is consistent with findings from a digital intervention study showing that structured modules can help parents feel more comfortable discussing sensitive topics with their adolescents and promote more open family communication [24].

In contrast, minimal change was observed on items assessing basic puberty and anatomical knowledge, likely reflecting ceiling effects due to high baseline correct-response rates. This pattern mirrors findings from other comprehensive sexuality education interventions, where the most pronounced improvements occur in domains with lower baseline understanding [25, 26]. The intervention, therefore, appeared to fill specific knowledge gaps rather than merely reinforcing well-established biological concepts. This selective pattern of improvement suggests that the mechanism of change was not simple information exposure, but rather targeted clarification facilitated through structured parental engagement.

These findings can be further understood through the lens of Empowerment Theory [13], which posits that enhancing knowledge and perceived competence facilitates meaningful behavioural engagement. By equipping parents with structured SRH content and professional guidance, the intervention may have strengthened their confidence to initiate and sustain parent–adolescent communication on sexual issues (PACS), thereby translating parental empowerment into improved adolescent knowledge. Similar improvements in communication, self-efficacy, and responsiveness have been observed in parent-based sexuality education programmes, reinforcing the value of family-based approaches in sexual health education [11, 27].

Complementing this, Ecological Systems Theory [14] highlights the role of the family as a proximal microsystem capable of reinforcing or supplementing formal education, particularly in culturally sensitive settings. Situating SRH discussions within this microsystem, while aligning with prevailing cultural norms, supports broader recommendations that emphasize the importance of sociocultural sensitivity in the design of SRH education initiatives, particularly in culturally conservative settings like Malaysia [23].

This pilot study has several strengths. First, it evaluated a structured, theory-informed parent-mediated SRH intervention grounded in Empowerment Theory and Ecological Systems Theory, contributing a clear conceptual framework for family-based adolescent health promotion. Second, the intervention demonstrated high retention (89.3 %), suggesting feasibility and acceptability within participating families. This engagement was likely bolstered by the use of accessible, low-cost digital infrastructure, specifically the Google website platform and WhatsApp, which reduced participation barriers for parents. Third, the involvement of Family Medicine Specialist trainees provided a bridge between clinical expertise and the home microsystem, enhancing parental technical support and communication self-efficacy. Finally, the analysis moved beyond composite scores to examine item-level patterns, revealing that the intervention yielded a large effect size in overall knowledge and was particularly effective in correcting deep-seated misconceptions in sensitive domains such as abortion safety and gender identity.

However, several limitations warrant consideration. The quasi-experimental single-arm pre–post design, without a control group, limits the ability to draw definitive causal inferences regarding the intervention's effectiveness. The relatively short follow-up period also precludes assessment of long-term knowledge retention and behavioural outcomes. Additionally, the sample was relatively homogeneous, consisting predominantly of Malay Muslim families with higher educational backgrounds, which may limit the generalizability of the findings to more diverse cultural, ethnic, and socioeconomic populations beyond the Malaysian context.

Another key limitation is the lack of control over intervention delivery at the household level. As parents implemented the content independently, there was likely variability in communication styles, fidelity to the provided materials, accuracy of information conveyed, and levels of parent–adolescent engagement. This heterogeneity in implementation may have influenced the observed outcomes and introduced potential performance bias that was not systematically measured.

Future research may consider to employ more rigorous designs, including randomized controlled trials with extended follow-up periods, to evaluate sustained knowledge retention and behavioural outcomes. Incorporating measures of intervention fidelity, such as structured delivery protocols, monitoring tools, and process evaluations would strengthen internal validity and clarify implementation consistency. Additionally, recruiting participants from more socioeconomically and culturally diverse populations across multiple settings will be essential to enhance external validity and support the broader applicability of these findings.

Conclusions

This pilot study demonstrates that empowering parents with structured, culturally sensitive sexual and reproductive health (SRH) content and professional support is associated with meaningful improvements in adolescents' SRH knowledge. The findings support the role of parent–adolescent communication on sexual issues as a complementary pathway to school-based education, particularly in addressing misconceptions, strengthening preventive literacy, and clarifying socially sensitive concepts. Importantly, the study highlights the need to align family-based SRH education with prevailing sociocultural norms and values to enhance acceptability, feasibility, and sustained engagement across different settings.

The use of accessible digital platforms alongside professional guidance demonstrates a feasible and scalable approach to supporting parents as primary health educators within the home. This approach is especially relevant in diverse global contexts, including resource-limited and culturally conservative environments where formal SRH education may be limited, inconsistent, or contested. By leveraging digital tools and family engagement, this model offers a flexible strategy that can be adapted across varying health systems and cultural landscapes.

These findings provide preliminary support for parent-mediated sexual and reproductive health interventions as a culturally appropriate strategy to improve adolescents' knowledge. Further research across diverse sociocultural contexts is needed to confirm their broader applicability and long-term impact.

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Research ethics: This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Universiti Kebangsaan Malaysia Research Ethics Committee (Reference No: JEP-2024-684).

Informed consent: Informed consent was obtained from all parents and assent was obtained from adolescents prior to participation.

Author contributions: NAM conceptualized the study and drafted the manuscript. NAAR and FMMK conducted data collection and contributed to the initial draft. AZA performed the statistical analysis. SRMA and AAZ reviewed the manuscript and provided critical input. All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Use of Large Language Models, AI and Machine Learning Tools: AI tools were used to assist in refining the grammar and language of the manuscript. All content was reviewed and approved by the authors.

Conflict of interest: The authors state no conflict of interest.

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Data availability: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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