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Advances in the Study of Risk Prediction Models for Postpartum Pelvic Floor Dysfunction Diseases

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Abstract: *Pelvic Floor Dysfunction (PFD) is an umbrella term for a range of disorders affecting the function of the pelvic floor muscles and tissues in women. It not only impacts the quality of life for women but can also lead to psychosocial issues. With the advancement of medical big data and artificial intelligence technologies, the study of disease prediction models has become a hot topic in the medical field. These models can assist physicians in early screening during pregnancy and the postpartum period to identify high-risk groups for disease development, allowing for proactive preventive measures and a reduction in disease incidence. This review aims to provide a comprehensive framework for identifying and discussing the strengths and limitations of existing models, as well as exploring potential directions for their development. The prediction models encompass a variety of types, from statistical methods to machine learning, including but not limited to nomograms, logistic regression, decision trees, support vector machines, and neural networks. We hope to provide valuable insights for clinicians, researchers, and policymakers, ultimately improving the prognosis and quality of life for postpartum patients.*

Keywords: *PFD, Prediction Models, Nomograms, Logistic Regression, Decision Trees*

1. Overview

1.1 Definition Pelvic

Postpartum pelvic floor dysfunction (PFD) is a clinical syndrome impacting women's health, often resulting from issues with the pelvic floor's supportive structures. It encompasses conditions like pelvic organ prolapse (POP), stress urinary incontinence (SUI), myofascial pelvic pain (MFPP), fecal incontinence (FI), and sexual dysfunction (SD) [1]. These conditions frequently co-occur, with POP and SUI being the most prevalent. POP involves the descent of pelvic organs—like the uterus, bladder, or rectum—into or out of the vagina due to weakened pelvic floor support. SUI occurs when urine leaks involuntarily during activities that increase abdominal pressure, such as coughing or exercising [2][3]. MFPP is characterized by chronic pelvic pain, often with a postpartum onset, which can present as occult pain and is associated with pelvic floor muscle or fascial tension/injury, potentially causing dyspareunia, lumbosacral pain, and lower abdominal discomfort. FI is the lack of bowel movement control, leading to involuntary defecation at inappropriate times or places. SD refers to issues in sexual activity and sensation, including reduced libido, dyspareunia, and orgasmic disorders.

1.2 Epidemiology

Pelvic Floor Dysfunction (PFD) conditions frequently coexist, with global adult female prevalence rates ranging from 10% to 58%. This variation underscores the influence of regional, ethnic, and lifestyle factors on a widespread health issue. A study at Belgium's University Hospital of Leuven reported that 92.8% of 208 pregnant women had one or more PFD symptoms between 28 to 32 weeks of gestation, with a decrease to 73.6% one year postpartum [4]. A social media survey of 2930 German women indicated that 49.4% experienced urinary incontinence (UI) symptoms, yet only 40.3% of PFD patients were inquired about UI or PFD by their gynecologists [5]. The University of Michigan research highlighted that PFD results in significant lifelong impacts for women, with over 300,000 annual surgical treatments, affecting 10% of the 3 million women who have vaginal deliveries each year [6]. A Swedish study of 898 first-time mothers identified postpartum incidence rates of fecal incontinence, defecatory dysfunction, and vaginal prolapse at 6%, 28%, and 8%, respectively, one year

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after childbirth [7]. A Japanese study of 212 first-time mothers found that 73.6% exhibited various types and degrees of PFD symptoms within 6 to 15 months postpartum [8]. According to Zhu Lan in the Chinese Clinical Guidelines for Pelvic Organ Prolapse (2020 Edition), a multicenter survey in China revealed that symptomatic POP affected 9.6% of adult women [9]. The UI prevalence in postmenopausal women in China reaches 50%, classifying it as a common chronic condition affecting women's health [10].

1.3 Risk Factors

PFD is associated with various risk factors, including pregnancy, childbirth—especially vaginal delivery with dystocia or obstetric instruments—age, and post-menopausal estrogen decline that weaken muscles and tissues [11]. Obesity is a notable risk factor, with chronic abdominal pressure from coughing, excess weight, or heavy lifting potentially damaging pelvic floor muscles. Lifestyle factors like diet, exercise, and occupation, as well as ethnicity and genetics, may affect PFD incidence and presentation. Vergeldt's review points to factors for POP and recurrence, including parity, delivery mode, age, BMI, smoking, HRT, physical activity, waist circumference, ethnicity, menopausal status, and family history [12]. B.'s study suggests cervical insufficiency may be linked to POP and urinary symptoms through shared mechanisms like tissue defects [13]. Identifying these factors is crucial for understanding PFD complexity and guiding prevention and treatment strategies.

2. Current State of PFD Risk Prediction Model Research Domestically and Internationally

2.1 International Research Status

A review in the International Urogynecology Journal highlighted the distinction between causal and predictive models, emphasizing causal models' role in understanding pathophysiology, yet noting their limitations in providing personalized treatment or prevention strategies [14][15]. Cattani et al. identified age, childbirth history, genetics, hormonal levels, and menopausal status as independent risk factors for POP, impacting disease initiation and progression [16]. Predictive models have seen advancements, such as Istanbul University Medical Faculty's model predicting post-surgical SUI using seven factors [17], a Swedish model forecasting long-term PFD risk with pre-delivery variables [18], and the "UR-CHOICE" scoring system for prenatal PFD risk prediction in pregnant women [19]. However, models like K van Delft's for predicting LAM avulsion in primiparous women during childbirth have external validity issues, necessitating further evaluation [20]. Foreign research has made progress in PFD predictive models, yet they require more research and validation to improve universality and accuracy.

2.2 Domestic Research Status

Domestic research on postpartum PFD predictive models has advanced with medical big data and analytics. Fu Wenying et al. developed a nomogram model from 1,500 pregnant women, validated for discrimination and calibration [21]. Wang Jianliu et al. created an early POP prediction model from 2,247 postpartum women, validated for efficacy [22]. Chen Cong et al. constructed a risk nomogram for MFPP, validated for predictive accuracy [23]. Zheng Yuanyuan et al. developed a multifactorial model with a C-index of 0.789 [24]. Wu Zhirong et al. created a predictive nomogram using pre-pregnancy BMI for PFD rehabilitation prognosis [25]. Chen Jing et al. established a logistic regression-based nomogram identifying pregnancy interval as a PFD predictor in multiparous women [26]. He Yuxin et al. built an MFPP incidence model using a classification tree [27]. Tao Naijuan et al. used binary logistic regression for a risk model with high sensitivity and specificity, AUC of 0.97 [28]. Qiu Yichao et al. developed a nomogram with a high C-index (0.835) for early postpartum PFD risk factors [29].

Despite these developments, domestic research has challenges, including single-center analyses prone to bias and incomplete data, the need for improved sensitivity and specificity in some models, and a lack of extensive validation. There's also a need for increased clinical application and personalized intervention strategy development.

Both domestic and international research have progressed in PFD predictive models, but there's an urgent need for multicenter, prospective studies to confirm applicability and precision and explore clinical practice potential.

3. Overview of Risk Prediction Models

3.1 Definition and Application

Clinical Prediction Models (CPMs), also termed Clinical Prediction Rules, Risk Prediction Models, Predictive Models, or Risk Scores, utilize mathematical formulas to predict the likelihood of an individual having a specific condition or outcome currently or in the future. They are categorized as Diagnostic Models, focused on current conditions, and Prognostic Models, forecasting future outcomes [30][31]. The application context dictates this division; statistically, they are similar. CPMs are extensively applied in medical decision-making, quality management, and resource allocation [32].

3.2 Research and Development Process

CPM research involves formulating questions, selecting study types, design and execution, data management, quality control, model development, evaluation, validation, application, impact assessment, and updating [33]. The development cycle includes data collection, model building, performance assessment, validation, presentation, and periodic updates [34]. Research design selects study populations and analysis techniques. Data collection gathers clinical data, including predictors and outcomes. Model construction [35] applies statistical tools to select factors and build preliminary models. Performance is gauged by sensitivity, specificity, and accuracy. Validation [36] tests model accuracy on new data. Optimization refines model parameters to boost performance. Presentation formats models for professional use. Updates integrate new data and findings.

3.3 Commonly Used Models and Their Advantages and Disadvantages

Statistical methods like linear and logistic regression are fit for straightforward models [37]. Complex, large-scale data sets benefit from machine learning algorithms such as random forests and gradient boosting machines, as well as deep learning [38]. Presentation methods like nomograms offer visual risk estimation, while mobile apps provide accessible risk assessment tools [39][40]. Online calculators will further facilitate immediate risk assessments. Model updating, crucial for adapting to clinical and treatment changes, ensures models remain current with emerging patterns [41][42].

Clinical prediction models are essential in medical decision-making, offering robust support for risk and prognosis assessment by merging clinical data with advanced analytics. As technology progresses, models will increase in precision and customization, providing enhanced utility for healthcare providers, patients, and decision-makers [43].

4. Three-Level Prevention of Postpartum Pelvic Floor Dysfunction Diseases

Under the current development trend of disease prediction models, the three-tiered prevention strategy for pelvic floor diseases can be further expanded and optimized to achieve more effective disease management and patient care. The following is a discussion of the three-tiered prevention strategy for pelvic floor diseases in conjunction with the development trend of disease prediction models:

4.1 Primary Prevention: Risk Assessment and Health Promotion

Primary prevention focuses on pre-disease assessment and intervention. Advanced prediction models can be used to assess the risk of pelvic floor diseases in women as early as the first trimester of pregnancy or even preconception. These models typically combine genetic information, lifestyle factors, and past medical history to identify high-risk groups through machine learning algorithms. Subsequently, health education, lifestyle guidance (such as a balanced diet and appropriate exercise), and behavioral interventions are employed to reduce the risk of disease [44].

4.2 Secondary Prevention: Early Diagnosis and Timely Treatment

In secondary prevention, the emphasis is on early diagnosis and treatment of the disease. With the development of wearable devices and mobile health technology, real-time monitoring of pelvic floor muscle function has become possible. Combined with regular biomarker testing and electronic health records, sensitive diagnostic models can be constructed for early disease recognition [45][46].

Moreover, through telemedicine and mobile applications, patients can quickly obtain professional medical advice for early treatment.

4.3 Tertiary Prevention: Disease Management and Rehabilitation

Tertiary prevention targets end-stage disease management, rehabilitation, and recurrence prevention. Models assess risks of progression and recurrence to offer tailored rehab plans and treatments. AI and big data allow for real-time patient monitoring and treatment response analysis, enabling timely strategy adjustments [47][48]. Psychological support and rehab guidance via support groups and community resources aim to restore patients' quality of life.

Modern predictive models trend towards integrating diverse data sources and cutting-edge technologies, including genomics, proteomics, metabolomics, deep learning, and natural language processing, to enhance predictive accuracy and customization. Patient participation and feedback mechanisms further refine models for practicality and efficacy. These models support a more precise, personalized three-tiered pelvic floor disease prevention strategy, integrating early risk assessment, real-time monitoring, disease management, and leveraging multi-source data and advanced technologies to boost prevention and treatment outcomes, ultimately improving patients' quality of life.

5. Conclusion

We've delved into the postpartum PFD prediction models, highlighting their role in women's health and the value of early diagnosis. Medical big data and AI advancements have made these models key for early PFD detection and management, using complex data sets and machine learning for personalized risk assessment.

Despite high precision, these models face challenges in generalizability and the need for regular updates. Future research must validate models across populations, integrate diverse data, adopt AI technologies like deep learning, and increase patient participation to improve model sophistication and accuracy.

Interdisciplinary collaboration, clinical integration, patient feedback, multidimensional evaluation, long-term follow-ups, policy development, international cooperation, technical training, and ethical privacy protection are crucial for advancing PFD model development. These initiatives aim to enhance the models' scientific rigor, practicality, and ethics, providing better health protection for women and new paths for disease prevention and management.

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