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Article

Market development trend and marketing strategy analysis of rehabilitation medical devices based on biomechanical principles

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Abstract: Based on the principle of biomechanics, this study analyzes in-depth the development trend and marketing strategy of the rehabilitation medical device market. It is found that the market is characterized by expanding scale, product diversification and intensifying competition, driven by policy support, market demand and technological innovation, but still facing constraints such as market competition, insufficient investment in research and development and shortage of talents. Marketing strategies such as product innovation, reasonable pricing, channel expansion and brand promotion are proposed, and the effectiveness of the strategies is verified with case studies. In order to promote the healthy development of the industry, it is suggested to increase policy support, upgrade the industrial chain, cultivate professional talents and strengthen international cooperation.

Keywords: biomechanics; rehabilitation medical devices; market trends; marketing strategies

1. Introduction

Under the background of the increasingly severe situation of population aging, the strengthening of the application of big data technology, the increasing trend of artificial intelligence, and the "medical and nursing" model of elderly care, the future demand for rehabilitation medical equipment products will continue to be released, showing a good momentum of development. According to the latest statistics, China's elderly population has exceeded 250 million, accounting for the proportion of the total population increases year by year, which directly promotes the expansion of the rehabilitation medical market [1]. In this context, the research and development and application of rehabilitation medical devices, as an important tool for auxiliary treatment and rehabilitation training, have received extensive attention. Biomechanics, as an interdisciplinary discipline integrating multidisciplinary knowledge of biology, mechanics, engineering, and medicine, provides a solid theoretical foundation and key technical support for the development of rehabilitation medical devices. Through the in-depth study of the mechanical behavior and physiological function of living organisms, biomechanics can not only reveal the mechanical mechanism of the rehabilitation process, but also guide the design and optimization of medical devices, thus improving the rehabilitation effect and reducing the treatment cost. The purpose of this paper is to analyze the current development trend of the rehabilitation medical device market in depth based on the principle of biomechanics, to explore the marketing strategy to adapt to the market demand, and to put forward targeted suggestions and countermeasures for the development status of China's rehabilitation medical device industry. This paper will refer to the latest market research reports,

scientific research papers, policy documents and other information, and strive to provide scientific and professional reference basis for the sustainable and healthy development of China's rehabilitation medical device industry.

2. Overview of biomechanical principles

2.1. Basic concept of biomechanics

Biomechanics is the science of studying the mechanical behavior of organism movement, organ and tissue function and interaction. It involves many subject areas such as physics, biology, medicine, engineering, etc. It is an important foundation for biomedical engineering, rehabilitation engineering, bionics, sports, aerospace and other fields, and is also a discipline that studies how organisms respond and adapt to internal and external mechanical environments. It combines knowledge from many fields such as biology, mechanics, physics, mathematics and engineering, and aims to reveal the mechanical properties and laws of living organisms under stress. In the research and development of rehabilitation medical devices, the basic concepts of biomechanics involve the relationship between force and motion, exploring the motion and deformation of organisms under the action of force, and its impact on the function and health of organisms; the study of the mechanical properties of materials, including the elasticity, plasticity, and viscoelasticity properties of biological tissues, as well as the changes of these properties over time and environmental conditions [2]; and also the analysis of fluid dynamics, i.e., blood , lymphatic fluid and other biological fluid flow characteristics and their mechanical effects in the body. In terms of mathematical expression, biomechanics is often used to describe the mechanical behavior of organisms by the following equations:

(1) Hooke's Law:

$$F = kx$$

where F is the force, k is the coefficient of elasticity, and x is the shape variable. This law describes the stress-strain relationship for elastomers in the elastic range.

(2) Newton's Second Law:

$$F = ma$$

where F is the force, m is the mass, and a is the acceleration. This law describes the relationship between force and motion [3].

2.2. Application of biomechanics in rehabilitation medical equipment

(1) Rehabilitation aids design: designers utilize the principle of biomechanics to design ergonomic rehabilitation aids according to the biomechanical parameters of different parts of the human body (e.g., joint moments, muscle strength, pressure distribution, etc.). For example, when designing a prosthesis, parameters such as ground reaction force, joint angle and moment during walking are considered to ensure the stability and comfort of the prosthesis [4].

(2) Product performance optimization: through biomechanical experiments and simulations, the performance of rehabilitation medical devices can be optimized. For example, Finite Element Analysis (FEA) is used to simulate the stress distribution of

the human skeleton when it is under stress, so as to optimize the structural design of the external fixator.

(3) Evaluation of rehabilitation effect: Biomechanical methods can be used to evaluate the effect of rehabilitation treatment. For example, kinetic analysis is used to assess the improvement of walking function of patients after using the rehabilitation robot. The formula is as follows:

$$\text{Walking Efficiency} = \frac{\text{mechanical power output}}{\text{metabolic energy expenditure}}$$

(4) Clinical decision support: By implementing biomechanical testing, including electromyography (EMG) analysis, pressure distribution measurement, and other techniques, it is possible to provide physicians with key physiological data about the patient's muscle activity, joint stability, and so on [5]. This precise information plays a crucial role in guiding the development of personalized rehabilitation treatment plans, helping to improve the effectiveness of treatment and the recovery process of patients.

3. Market development trends of rehabilitation medical devices based on biomechanical principles

3.1. Market size and growth trend

In recent years, with the improvement of China's healthcare level and aggravation of the aging population, the market size of rehabilitation medical devices has shown significant growth [6]. According to the latest market research report, the compound annual growth rate of China's rehabilitation medical device market is more than 15%, and it is expected that the market size will exceed RMB 100 billion in the next five years. This growth trend is mainly attributed to the national emphasis on the rehabilitation medical field and the increasing demand for high-quality rehabilitation services from the people.

3.2. Main product types and functions

Rehabilitation robots provide personalized rehabilitation training programs by simulating human joint movements, and have force feedback functions to adjust the training difficulty according to the patient's strength and range of motion to enhance the rehabilitation effect. Rehabilitation aids, such as prosthetics, orthotics, walking aids, etc., are designed based on human biomechanical characteristics to help patients recover or compensate for their functions. Rehabilitation evaluation equipment, including gait analysis system, electromyography, pressure tester, etc., objectively assesses the rehabilitation process and provides accurate data for treatment [7]. These products are not only used to assist training and enhance outcomes, but also aim to improve patients' quality of life, reduce complications, and provide remote rehabilitation services.

3.3. Market competition pattern

(1) Major enterprises and market share

Companies such as Rewalk Robotics of the United States and Siemens Healthineers of Germany have occupied a certain market share by virtue of technological innovation and brand influence. For example, Rewalk Robotics has a market share of about 15% in the field of rehabilitation robotics, and Siemens has a share of about 20% in the market of rehabilitation evaluation equipment. Enterprises such as Myriad Medical and Yuyue Medical have become leaders in the industry through technological research and development and market expansion [8]. Myriad Medical's share of the rehabilitation medical equipment market is approximately 10%, and Yuyue Medical's share is approximately 8%.

(2) Comparison of advantages and disadvantages of domestic and foreign enterprises

Technological advantages: International enterprises have advanced technology R&D capabilities and rich product lines, such as Rewalk Robotics' leading position in rehabilitation robotics. Domestic enterprises have advantages in cost control and localized services, such as Meizu Medical's outstanding performance in terms of product cost performance and after-sales service. Channel Advantage: International companies have globalized sales network and brand influence, such as Siemens' worldwide sales channels and brand recognition [9]. Domestic enterprises have extensive sales channels and deep market foundation in the domestic market, such as Yuyue Medical's extensive cooperation with hospitals at all levels in China. Other advantages: International enterprises have leading advantages in high-end products and innovative technologies. Domestic enterprises have advantages in policy support and market adaptability.

3.4. Market drivers and constraints

(1) Driving factors: market driving factors mainly include support from relevant departments, market demand and technological innovation. Relevant departments pay increasing attention to the field of rehabilitation medicine, such as the implementation of the Regulations on Rehabilitation of Disabled Persons, which creates a favorable policy environment for the development of rehabilitation medical devices [10]. With the pursuit of a healthy quality of life, there is a growing demand for rehabilitation medical treatment, especially among the elderly, the disabled and the chronically ill. The integration and innovation of biomechanics, artificial intelligence, 3D printing and other technologies have injected new vitality into the research and development of rehabilitation medical devices and promoted the sustainable development of the industry. The trend of population aging is obvious, and the proportion of elderly people is increasing, the demand for rehabilitation medical equipment grows accordingly. Adjustments in health insurance policies, such as the inclusion of more rehabilitation medical devices in the scope of health insurance reimbursement, have reduced the cost of use for patients, further releasing market demand [11].

(2) Constraints: Increased market competition is an important constraint to the development of the rehabilitation medical device market. With the increase in the number of market participants, companies are facing greater pressure and must be more precise in market positioning and product differentiation. Insufficient investment in R&D is also a key issue restricting the development of the industry [12]. Some

enterprises are unable to fully invest in R&D due to financial constraints, resulting in the speed and quality of product innovation being affected. Talent shortage is also prominent, the research and development of rehabilitation medical equipment requires interdisciplinary professionals, and China's relative lack of talent in this area, which undoubtedly limits the rapid development of the industry. These three factors together constitute the main constraints on the development of the current rehabilitation medical equipment market.

3.5. Market competition pattern

The competitive landscape of the rehabilitation medical equipment market is becoming increasingly fierce, with both domestic and foreign enterprises actively laying out their business. In the international market, the U.S. Rewalk Robotics, Germany Siemens Healthineers and other companies have occupied a certain market share by virtue of their technological innovation and brand influence. In the domestic market, enterprises such as Myriad Medical and Yuyue Medical have become leaders in the industry through continuous technological research and development and market expansion [13]. With the optimization of the entrepreneurial environment, a number of innovative enterprises focusing on rehabilitation medical devices are also rising rapidly, and the market competition is becoming increasingly diversified.

3.6. Market drivers and restraints

(1) Driving factors: market driving factors mainly include support from relevant departments, market demand and technological innovation. Relevant departments pay increasing attention to the rehabilitation medical field, such as the implementation of the Regulations on Rehabilitation of Disabled Persons, which creates a favorable policy environment for the development of rehabilitation medical devices. With the pursuit of a healthy quality of life, there is a growing demand for rehabilitation medical treatment, especially among the elderly, the disabled and the chronically ill. The integration and innovation of biomechanics, artificial intelligence, 3D printing and other technologies have injected new vitality into the research and development of rehabilitation medical devices and promoted the sustainable development of the industry [14].

(2) Constraints: Increased market competition is an important constraint to the development of the rehabilitation medical device market. With the increase in the number of market participants, companies are facing greater pressure and must be more precise in market positioning and product differentiation. Insufficient investment in R&D is also a key issue restricting the development of the industry. Some enterprises are unable to fully invest in R&D due to financial constraints, resulting in the speed and quality of product innovation being affected [15]. Talent shortage is also prominent, the research and development of rehabilitation medical equipment requires interdisciplinary professionals, and China's relative lack of talent in this area, which undoubtedly limits the rapid development of the industry. These three factors together constitute the main constraints on the development of the current rehabilitation medical equipment market.

4. Marketing strategy of rehabilitation medical devices based on the principle of biomechanics

4.1. Product strategy

Product strategy is crucial in the marketing strategy of rehabilitation medical devices based on biomechanical principles. Enterprises should devote themselves to product innovation, improve product added value, and keep up with the latest research results in the field of biomechanics. In the process of product development, patient feedback and user experience data are highly valued as an important basis for product optimization [16]. For example, when developing an intelligent rehabilitation robot, it is not only required to be able to adjust the training program based on real-time patient feedback, but also to continuously optimize the robot's algorithms and functions by collecting and analyzing a large amount of user experience data. Similarly, when using 3D printing technology to provide patients with personalized and customized rehabilitation aids, the feedback from patients should be fully considered to continuously adjust and improve the product design to ensure that the product is better adapted to the biomechanical characteristics of each patient [17]. In addition, when integrating multiple rehabilitation functions into a single device, the functional layout and operation interface should also be optimized based on user experience data to enhance the comprehensive performance and user experience of the product.

4.2. Price strategy

(1) Cost control: Effective cost reduction through optimization of supply chain management and improvement of production efficiency, creating room for reasonable pricing of products. For high-end rehabilitation robots and basic auxiliary equipment, there are significant differences in cost structures, with high-end products usually involving more complex R&D and higher material costs, while basic auxiliary equipment focuses on large-scale production and cost control.

(2) Tiered pricing: Products with different configurations and functions are introduced for consumers with different financial capabilities to meet multi-level market demand. In the high-end market, consumers have lower price elasticity and pay more attention to the technical content and rehabilitation effect of the products; while in the basic auxiliary equipment market, price elasticity is higher and consumers are more sensitive to price.

(3) Value pricing: Based on the actual value provided by the product, such as the rehabilitation effect and ease of use, etc., reasonable pricing is carried out to ensure that the price of the product matches its value, so as to meet the needs of consumers at different levels. For high-end rehabilitation robots, the pricing should reflect their advanced technology and significant rehabilitation effects; for basic auxiliary equipment, it should focus on cost-effectiveness to ensure that the price is affordable.

4.3. Channel strategy

Based on the principle of biomechanics, the marketing strategy of rehabilitation medical devices in terms of channels, enterprises should implement the strategy of synchronizing online and offline efforts to broaden sales channels. Establish an official

e-commerce platform to take advantage of the Internet for online display, consultation and sales of products; strengthen cooperation with offline channels such as hospitals, rehabilitation centers, pharmacies, etc., to build a stable sales and service network; seek opportunities for cross-border cooperation, and work hand in hand with medical and healthcare related industries such as insurance, tourism, etc., to explore new sales channels, in order to achieve an all-rounded coverage of the product market [18].

4.4. Marketing strategy

When promoting rehabilitation medical devices based on biomechanical principles, attention should be paid to brand building, and a good brand image should be established by providing high-quality products and services. In the process of marketing strategy optimization, make full use of patient feedback and user experience data to pinpoint market demand and consumer preferences. For example, by analyzing user discussions and feedback in social media, professional forums and industry conferences, we can understand consumers' concerns about products and suggestions for improvement, and then adjust marketing strategies and promotional focus. At the same time, we actively collect and share successful rehabilitation cases, and demonstrate product effectiveness with user experience data to enhance the credibility and attractiveness of the products with empirical results [19]. In addition, when providing professional training for healthcare professionals on product use and rehabilitation techniques, we should also incorporate patient feedback and user experience data to enhance the relevance and practicality of the training, so as to improve product reputation and overall awareness with the help of professional recommendations.

5. Case study

5.1. Product strategy analysis

Taking Enterprise A as an example, we will discuss in depth its product strategy and marketing strategy for rehabilitation medical devices based on biomechanical principles. In terms of product strategy, Enterprise A has demonstrated an outstanding spirit of innovation, highlighting the following three aspects of innovation:

(1) R&D innovation: In cooperation with a top biomechanics research institute, Enterprise A has invested huge R&D resources to develop a rehabilitation robot equipped with adaptive learning algorithms. The robot can dynamically adjust the training program according to the patient's rehabilitation progress and physiological feedback. **Table 1** below details the R&D investment and patent applications of Enterprise A in the past three years, with data collected from the company's annual report and patent database, and the timeframe is from 2021 to 2023. It is worth noting that 70% of the patents obtained by Enterprise A in the last three years have been successfully converted into actual products, reflecting a high patent conversion rate. Meanwhile, the average time-to-market for new products of Enterprise A is 12 months, demonstrating efficient R&D and marketability.

Table 1. Enterprise A's R&D investment and patent application in the past three years.

particular year	Investment in research and development ($ million)	Number of patent applications (pieces)
2021	1200	8
2022	1500	12
2023	1800	15

(2) Personalized customization: Enterprise A adopts advanced 3D scanning and 3D printing technology to customize personalized rehabilitation aids to meet individualized needs and help patients recover. The case is as follows: After using the customized prosthesis, Mr. Zhang's walking stability increased by 30% and his quality of life improved significantly. The data for this case was collected from the patient's rehabilitation tracking record, and the time frame was six months after the prosthesis was used.

(3) Functional integration: The rehabilitation training equipment developed by Enterprise A integrates a number of advanced functions such as EMG monitoring and gait analysis, realizing a comprehensive improvement in product performance. The actual impact of function integration on patients is as follows: Ms. Li, a patient, improved her gait coordination by 20% and shortened her rehabilitation period by 15% through the use of the device for training. The data for this case was collected from the patient's rehabilitation training records, and the time frame was three months after the device was used. **Table 2** below shows the integration of the diverse functions of the rehabilitation training device in detail:

Table 2. Multifunctional integration of a model of rehabilitation training equipment in enterprise A.

functional module	descriptive
Electromyography monitoring	Real-time monitoring of muscle activity
gait analysis	Analyzing the postural and kinetic characteristics of patients while walking
Training Feedback	Provide visual and auditory feedback to guide training

5.2. Marketing strategy analysis

(1) Pricing strategy: Enterprise A adopts the cost-plus pricing method, combined with market research data, to set a reasonable and competitive price range for its products. **Figure 1** visualizes the price comparison between the price of Enterprise A's products and that of similar products in the market, highlighting the precision and originality of Enterprise A's pricing strategy.

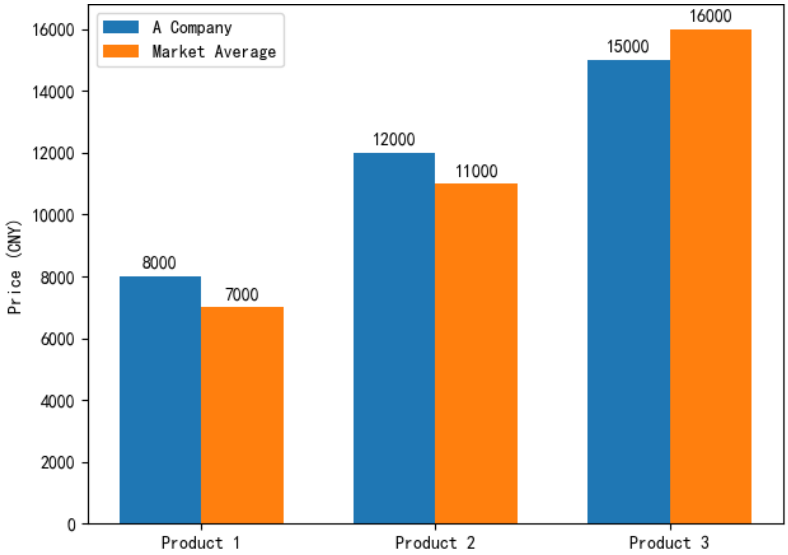

Figure 1. Comparison of product price of enterprise A with the price of similar products in the market.

(2) Channel strategy: Enterprise A has realized the organic combination of online e-commerce platform and offline medical channels, forming a comprehensive product coverage network. According to the data provided in **Table 3**, we can clearly see the proportion distribution of Enterprise A in online and offline sales channels, and this strategy has effectively broadened the market reach and enhanced the penetration of product sales.

Table 3. Proportion of online and offline sales of enterprise A.

sales channel	Sales ratio (%)
on-line	60
below the line	40

(3) Promotion strategy: Enterprise A actively adopts diversified promotion means, including participation in industry exhibitions, publication of professional academic papers and marketing activities on social media platforms, which effectively enhance the brand's industry influence and public recognition. According to the data provided in **Table 4**, we can clearly see the remarkable effectiveness of Enterprise A's brand promotion activities.

Table 4. Effectiveness of branding activities of enterprise A.

promotional activity	Number of people covered (10,000)	Increased brand recognition (%)
Industry Exhibitions	5	15
academic paper	2	10
social media	10	20

5.3. Analysis of market performance

(1) Sales growth trend: **Figure 2** shows in detail the sales growth trajectory of Enterprise A over the past three years. Through this chart, we can intuitively observe

the steady increase in enterprise sales, reflecting the company's strong momentum in market competition.

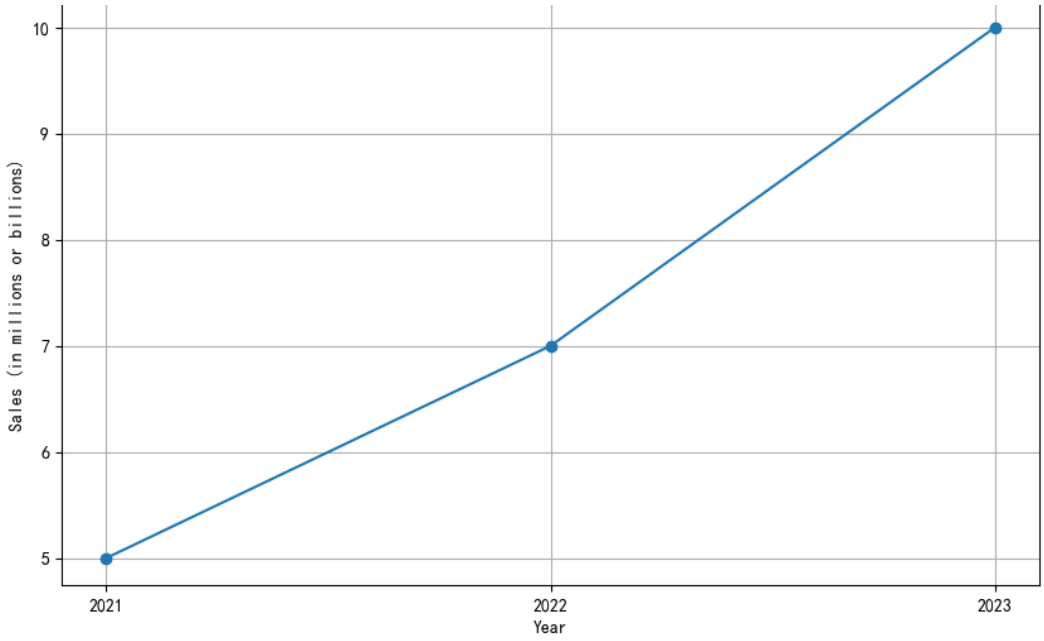

Figure 2. Sales growth of enterprise A in the last three years.

(2) Market share analysis: **Table 5** presents in detail the market share of Enterprise A in the rehabilitation medical equipment market. It can be visualized that the share of enterprise A in the rehabilitation medical equipment market is increasing year by year, which reflects its market competitiveness.

Table 5. Market share of firm A in the rehabilitation medical devices market.

particular year	Market share (%)
2021	5
2022	7
2023	10

6. Countermeasures and suggestions for China's market development

In order to promote the high-quality development of China's market, the government should increase policy support, introduce preferential policies such as tax relief, R&D subsidies, intellectual property protection, etc., to incentivize enterprises to increase R&D investment and promote technological innovation. Establish a national rehabilitation medical device R&D platform to focus advantageous resources on solving key technological problems and enhance the industry's R&D level. Through the establishment of rehabilitation medical equipment industrial parks, give full play to the clustering effect, promote the collaboration of upstream and downstream enterprises in the industrial chain, optimize the supply chain management, and improve the overall level of the industrial chain. Promote intelligent manufacturing and green production technology, improve production efficiency and

product quality, reduce costs and environmental pollution. Strengthen cooperation with colleges and universities and scientific research institutions, establish a talent training system integrating production, learning and research, cultivate interdisciplinary composite talents, carry out professional skills training, improve the quality of employees and enhance the competitiveness of enterprises. Actively expand international cooperation, encourage enterprises to establish cooperative relationships with internationally renowned enterprises and research institutions, introduce advanced technology and management experience, support enterprises to participate in the formulation of international standards, enhance the competitiveness of China's products in the international market, and realize high-quality leap in industrial development.

7. Conclusion

Based on the principle of biomechanics, this paper provides an in-depth analysis of the market development trend and marketing strategy of rehabilitation medical devices in China. The study shows that the market demand for rehabilitation medical devices continues to grow against the background of increasing population aging and rising incidence of chronic diseases. The application of biomechanics in the research and development of rehabilitation medical devices provides strong support for product innovation. Currently, the rehabilitation medical device market is characterized by scale expansion, product diversification, and competition intensification, and is also driven by policy support, market demand, and technological innovation, but it also faces constraints such as market competition, insufficient investment in R&D, and shortage of talents. In view of the current market situation, this paper proposes marketing strategies such as product innovation, reasonable pricing, channel expansion and brand promotion, and verifies the effectiveness of these strategies by combining with the case study of enterprise A. In order to promote the sustainable and healthy development of China's rehabilitation medical device industry, this paper suggests increasing policy support, upgrading the industrial chain, cultivating professional talents and strengthening international cooperation.

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

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