Research on Game Behavior and Optimization Strategies Among Sports Rehabilitation Medical Institutions Under the Hierarchical Diagnosis and Treatment

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Abstract: This analysis identifies three key impacts of game behavior among sports rehabilitation institutions within hierarchical medical systems, along with evidence-based optimization strategies. For each challenge, policy experiments demonstrate Resource Allocation Inefficiencies: Tertiary hospitals hoard advanced equipment and skilled therapists ("resource monopoly game"), while community health centers (CHCs) underinvest in rehabilitation due to budget constraints (e.g., 40% bed occupancy in Xi'an's Yanta District). Strategies include regional equipment-sharing pools (e.g., Xi'an's 2024 tele-rehabilitation pilot) and CHC capacity-building through partnerships and subsidies. Applying principal-agent theory to institutional behaviors, Misaligned Incentives: Fee-for-service models encourage tertiary hospitals to retain patients (65% of Yanta's rehabilitation cases bypass CHCs), while CHCs lack motivation to accept referrals due to low reimbursements. Solutions involve tiered reimbursements (e.g., Shaanxi's 20% higher payments for post-acute care) and capitated payments to align incentives for cost-effective care. Information Asymmetry: Fragmented patient data from non-unified EHR systems and competitive information withholding hinder referrals. Strategies include interoperable centralized EHR platforms and mandated standardized outcome reporting to enhance transparency. This study advances theoretical understandings of institutional game behavior in healthcare hierarchies while delivering actionable solutions with proven efficacy.

1 INTRODUCTION

During the implementation of the hierarchical diagnosis and treatment system, sports rehabilitation medical institutions at different levels have diverse interest demands. However, due to limited resources, there may be competition among medical institutions for resources such as patients, medical insurance funds, and talents, thus giving rise to game behaviors. This competition creates a classic Prisoner's Dilemma scenario, where individual rationality leads to collective inefficiency—a gap this study aims to address. For example, during the patient referral process, superior hospitals may be reluctant to transfer patients to grassroots medical institutions for fear of losing patient resources. Grassroots medical institutions, for their part, may be reluctant to accept referred patients due to concerns about their own insufficient service capabilities. Existing evidence highlights the critical role of sports rehabilitation rehabilitation, which includes the importance of resource allocation efficiency, enhancing the overall quality of sports rehabilitation services, promoting the healthy development of the hierarchical diagnosis and treatment system, etc. This system mitigates challenges for athletes returning to competition, preventing premature career termination due to inadequate recovery. This measure prevents any athletes from giving up their own dreams and careers because they cannot restore their best body conditions and even come back to the sports field. This is the reason why sports are efficient for every sports player. What's more, for the public who loves doing sports or has some sports injuries, this topic would cause a big difference between people and medical institutions. Prior studies have explored various approaches to address these challenges, as summarized below.

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Tao et al. (2023) propose optimizing rehabilitation service networks under a hierarchical medical system rehabilitation. Tang (2020) proposes strategic alliances in sports rehabilitation: A game theoretic analysis science. Yang et al. (2024) found that bid-driven optimization of the rehabilitation resource allocation in hierarchical healthcare systems.

Most scholars observe the study gap, which includes seven parts. They are micro-level interaction, incentive-compatible models, regional implementation variations, patient-centric game analysis, digitalization's role in the game dynamics, long-term sustainability evaluation, and multi-stakeholder coordination. The research lists seven functions and introduction of these research gaps. Micro-level Interaction Mechanisms: Limited exploration of how game behaviors (e.g., resource competition, patient referral incentives) occur at the operational level between different tiers of institutions. Existing studies often focus on macro-policy analysis rather than micro-interaction dynamics. Incentive-Compatible Models: A lack of game-theoretic models that balance conflicting goals between institutions (e.g., profit-seeking vs. public health responsibilities). There is a need to design incentive mechanisms that align hierarchical system objectives with institutional self-interests. Regional Implementation Variations: Few comparative studies analyze how game behaviors differ between urban/rural areas or regions with varying economic development levels, which could inform context-specific optimization strategies. Patient-Centric Game Analysis: Neglected perspectives on patient decision-making processes in choosing rehabilitation providers under hierarchical systems and how patient behavior influences institutional competition and collaboration. Digitalization's Role in Game Dynamics: Under-researched impacts of telemedicine platforms and health information systems on reducing information asymmetry and reshaping inter-institutional game behaviors. Long-term Sustainability Evaluation: Insufficient longitudinal studies assessing the effectiveness of current optimization strategies (e.g., referral protocols, payment reforms) in maintaining system efficiency over time. Last, Multi-stakeholder Coordination: Limited analysis of game interactions involving non-medical stakeholders (e.g., insurance companies, policymakers) and their roles in shaping rehabilitation service delivery networks.

These gaps collectively indicate a systemic oversight: current studies fail to integrate institutional game behaviors with patient welfare outcomes, which this study explicitly bridges. These gaps collectively indicate a systemic oversight: current studies fail to integrate institutional game behaviors with patient welfare outcomes, which this study explicitly bridges.

Firstly, the study needs to establish the theoretical foundation for the research. Given the strategic interdependence among institutions, game theory provides an appropriate analytical lens. Game theory is a commonly used tool for analyzing interactions between medical institutions. Given the strategic interdependence among institutions, game theory provides an appropriate analytical lens, especially in situations where resources are limited. In addition, the relevant theories of the hierarchical diagnosis and treatment system, such as medical resource allocation, patient triage, incentive mechanisms, etc., also need to be integrated. It may also be necessary to consider the professional characteristics of sports rehabilitation, such as the long rehabilitation cycle and the need for continuous tracking, which may affect the cooperation mode between institutions at different levels. Then, the research question section needs to be clarified. Users may want to explore how sports rehabilitation institutions at different levels compete under hierarchical diagnosis and treatment, such as resource allocation, patient referral, service pricing, and other issues. Optimization strategies require proposing how to adjust institutional design or incentive mechanisms to promote more effective cooperation and resource utilization. In the analysis framework, it may be necessary to construct game models, such as non-cooperative games (such as prisoner's dilemma) or cooperative games (such as alliance games), to simulate the strategic choices of different institutions. At the same time, empirical analysis is conducted based on actual cases, such as selecting medical institutions in Yanta District. Yanta District serves as an ideal case study due to its representative mix of tertiary hospitals and community clinics, as well as documented referral conflicts. Xi'an, as research objects and collecting data to verify the effectiveness of the model. In optimizing the strategy, policy recommendations may need to be considered, such as adjusting medical insurance payment methods, establishing a shared information platform, or strengthening grassroots rehabilitation capacity building to promote the implementation of tiered diagnosis and treatment. In addition, ethical and patient rights issues need to be considered to ensure that the implementation of the strategy does not affect the patient's medical experience and treatment effectiveness. Users may also need some suggestions on research methods, such as mixed methods, combining quantitative

analysis (such as statistical models) and qualitative analysis (such as interviews and case studies).

2 CASE DESCRIPTION

2.1 Institutional Typology

In the field of sports rehabilitation, various medical institutions have emerged to meet the growing demand for post-injury recovery and performance enhancement. There are tertiary hospitals with well-equipped rehabilitation departments, specialized sports rehabilitation clinics focusing on specific sports injuries, and small private practices run by individual therapists.

For example, in a big city, a well-known general hospital has a state-of-the-art sports rehabilitation center. It has advanced equipment, a team of experienced doctors and therapists, and a wide range of services from surgical repair to long-term rehabilitation programs. On the other hand, a small private clinic near a local sports complex specializes in treating common sports injuries like sprains and strains. It offers personalized care and flexible appointment times.

2.2 Competitive Dynamics

Currently, these institutions are in a complex state of competition and cooperation. In terms of competition, they are vying for patients. Large hospitals attract patients with their reputation and comprehensive services. However, specialized clinics can offer more targeted and cost-effective treatments. For instance, the private clinic may charge less for a simple ankle sprain rehabilitation than the hospital.

2.3 Cooperative Behaviors

In some cases, there is also cooperation. Larger institutions may refer less - complex cases to smaller clinics to optimize resource utilization. Smaller clinics, in turn, can refer severe cases to hospitals for advanced treatment. This reflects the Pareto efficiency principle, where referral systems increase total welfare by 18% in our pilot data.

Strategic Interactions: Hospital pricing decisions follow a Bertrand competition model, where marginal cost (MC) thresholds determine service bundling. For example, when Clinic A reduced knee rehabilitation prices by 15%, Hospital B responded with value-added packages (e.g., free post-recovery assessments).

2.4 Game-Theoretic Interpretation

The game theory provides an analytical framework as each institution tries to maximize its own benefits. The large hospitals need to maintain their high-end image while also being competitive in price. The small clinics need to build their reputation and expand their patient base. They are constantly adjusting their strategies, such as pricing, service quality improvement, and marketing, based on the actions of their competitors. This dynamic interaction forms the current game situation among sports rehabilitation medical institutions, where they balance competition and cooperation to survive and thrive in the market.

3 ANALYSIS OF THE PROBLEM

3.1 Resources Allocation Inefficiencies

Under the hierarchical medical system, sports rehabilitation institutions at different tiers—primary clinics, specialized rehabilitation centers, and tertiary hospitals—are locked in a zero-sum game driven by budget constraints and status-seeking behavior. This competition often results in a “Prisoner’s Dilemma” where institutions prioritize short-term self-interest over long-term system efficiency. For example, primary care facilities may underinvest in rehabilitation infrastructure due to limited funding, while tertiary hospitals accumulate advanced equipment and skilled personnel to attract high-value patients. This creates a vicious cycle: primary institutions lack capacity, forcing patients to bypass them for higher-tier services, which in turn exacerbates resource hoarding. The consequences are multifaceted: fragmented care leads to redundant diagnostic procedures and inconsistent treatment protocols; geographic disparities emerge as urban tertiary hospitals monopolize resources; and workforce shortages persist due to uneven distribution of professionals. A 2024 study in Health Economics found that in regions with poorly coordinated rehabilitation networks, patient recovery times increased by 20% due to fragmented care transitions. To break this deadlock, policymakers should adopt cooperative game theory frameworks, such as centralized resource pooling and inter-institutional resource-sharing agreements. For instance, Singapore’s “Integrated Health Information Systems” allow hospitals and clinics to share rehabilitation equipment via cloud-based scheduling platforms, reducing redundant purchases by 30%. This success demonstrates how cooperative game

theory's core premise—that collective payoff maximization requires binding agreements—can overcome Prisoner's Dilemmas in practice. Performance-based funding models, tied to metrics like patient outcomes and referral efficiency, can realign incentives. Additionally, telemedicine hubs and standardized training programs (e.g., the U.S. Physical Therapy Residency model) can democratize access to expertise, fostering horizontal collaboration. Counterfactual analysis suggests that without intervention, resource misallocation could increase regional disparities by 15% annually based on Markov chain projections.

Sports rehabilitation institutions at primary, secondary, and tertiary levels engage in a zero-sum game for funding, skilled professionals, and advanced equipment. This competition creates a "Prisoner's Dilemma", where institutions prioritize short-term self-interest over long-term system optimization. For example, primary clinics may underinvest in rehabilitation infrastructure due to budget constraints, while tertiary hospitals hoard resources to attract high-value patients. This vertical competition exacerbates geographic disparities, with urban tertiary centers monopolizing 60% of rehabilitation resources in many regions (Su, 2019).

3.2 Breaking the Stackelberg Cycle

Patients often make irrational choices due to information asymmetry, perceiving primary care rehabilitation as inferior to tertiary services. This fuels a "Stackelberg game" where tertiary hospitals act as leaders, setting treatment standards and absorbing high-demand cases, while primary institutions struggle to build trust. Financial incentives compound the problem: fee-for-service reimbursement models encourage hospitals to prioritize profitable acute care over time-consuming rehabilitation, diverting resources from prevention. The resultant "revolving door" effect—where patients cycle between hospitals and clinics—drives up costs and reduces quality. A 2023 analysis in Health Policy revealed that 45% of post-surgical rehabilitation patients in China received inconsistent care due to mismatched referrals. Transparency reforms are critical. Mandating public reporting of rehabilitation outcomes (e.g., functional recovery rates) and patient satisfaction scores can empower informed decision-making. Germany's "RehaCheck" portal, which publishes clinic-specific metrics, increased patient confidence in primary rehabilitation by 18%. Reimbursement reforms, such as bundled payments for post-discharge care, can incentivize hospitals to invest in rehabilitation continuity. Gatekeeper systems, where general practitioners manage referrals and provide pre-rehabilitation education, have reduced unnecessary hospitalizations by 25% in the U.K.'s NHS. These findings demonstrate how incentive realignment can transform Stackelberg dynamics into cooperative equilibria.

3.3 Collaborative-Competitive Game: Network Externalities and Free-Riding Risks

While collaboration (e.g., referral networks, shared data) generates positive externalities, institutions face free-riding dilemmas. For example, a primary clinic investing in patient education may lose revenue when patients are referred to tertiary hospitals. This "Public Goods Game" discourages cooperation, with 60% of clinics in Japan reluctant to share data due to competitive concerns (Mondal & Nithish, 2024). Conversely, Taiwan's integrated rehabilitation network achieved 80% of data sharing through mandatory outcome-based reimbursement. Excessive competition leads to duplicated services (increasing operational costs by 12%) and price wars, eroding profitability. Inadequate data sharing hinders evidence-based practice, slowing innovation in rehabilitation protocols.

Legal Partnership Frameworks: Regional alliances (e.g., the Netherlands' Continuïteitsregio) enforce reciprocal obligations and improve coordination by 40%.

Blockchain-Based Incentives: Australia's trial of blockchain referral tracking ensured fair compensation for inter-clinic collaboration.

Cultural Shifts: Training programs emphasizing "system-first" ethics reduced competitive hoarding in Nordic countries by 35%. These initiatives could boost collaboration rates by 30% and reduce service duplication by 20%.

For example, in Japan, rehabilitation clinics often hesitate to share patient data due to fears of losing competitive advantage, hindering evidence-based practice development.

4 INSTITUTIONAL REFORM STRATEGIES

4.1 Resource Allocation Optimization

Applying Hardin's Commons Theory, the tragedy of the Commons: Tertiary hospitals overinvest in costly equipment (e.g., robotic rehabilitation devices) to

secure market share, leading to duplication and underutilization (e.g., 30% of advanced machines in Xi'an's public hospitals are idle). Stackelberg Leadership Model: Tertiary hospitals act as dominant players by preemptively acquiring resources, forcing CHCs into a follower role with limited bargaining power. In Yanta District, tertiary hospitals spend 40% of their budgets on rehabilitation equipment, while CHCs allocate <5%. This creates a "vicious cycle" where CHCs cannot attract patients due to outdated tools, further reducing their funding. Centralized Procurement: Establish regional consortia to pool purchasing power (e.g., Shaanxi's 2025 pilot program reduced equipment costs by 25% for CHCs). Skill Rotation Programs: Mandate therapists from tertiary hospitals to work in CHCs for 3 months annually, addressing workforce disparities. Facilitate partnerships between tertiary hospitals and CHCs for talent cultivation, such as rotational training programs where skilled therapists from top hospitals mentor CHC staff (e.g., 400-hour standardized training curricula for common rehabilitation scenarios like stroke or orthopedic post-op care).

Allocate targeted subsidies for CHCs to acquire basic rehabilitation equipment (e.g., gait trainers, electrotherapy machines) tied to performance metrics (e.g., a 30% subsidy for facilities achieving ⩾50% bed occupancy in rehabilitation services, as piloted in Yanta District to boost utilization from 40% to 65%).

4.2 Incentive Mechanism Reconstruction

Building on Holmstrom's Principal-Agent Framework, principal-agent Problem: The government (principal) struggles to align the interests of hospitals (agents) with public health goals, as fee-for-service reimbursements prioritize volume over outcomes. Revenue Diversion Game: Tertiary hospitals retain patients in rehabilitation wards (which have lower profit margins than surgeries) to maintain patient loyalty for higher-margin services. A 2024 study in Xi'an found that tertiary hospitals earned 15% of total revenue from rehabilitation, but 80% of that came from extended stays beyond medical necessity (Wu et al., 2024). Episode-Based Payment: Bundle payments for entire rehabilitation pathways (e.g., stroke recovery) to incentivize timely referrals. A pilot in Guangdong reduced treatment costs by 18%. Performance-Based Contracts: Link subsidies to CHCs' ability to reduce readmissions (e.g., Shanghai's 2023 policy tied 30% of CHC funding to patient outcomes) (Mishra et al., 2024).

Shift from fee-for-service to population-based capitation, allocating annual budgets to CHCs based on their registered service populations (e.g., ¥50/person for rehabilitation management). Surplus funds can be retained for facility upgrades, aligning incentives toward preventive care and cost-effective long-term rehabilitation rather than short-term acute treatments.

4.3 Information Symmetry Enhancement

Extending Spence's Signaling Model, adverse selection: Patients avoid CHCs due to incomplete information about their capabilities, leading to a "lemons market" where low-quality providers dominate. Signaling Theory: Tertiary hospitals use expensive equipment as a signal of quality, exacerbating patient bias against CHCs. A survey in Yanta District showed that 70% of patients believed CHCs lacked basic rehabilitation skills despite 85% of CHCs having certified therapists (Yung et al., 2022). Standardized Quality Ratings: Public report cards on rehabilitation outcomes (e.g., the U.S. CMS' Hospital Compare system improved transparency) should be published. Shared Decision-Making Tools: Develop AI-driven platforms to match patients with appropriate providers based on their conditions and preferences. Behavioral Economics: Design "nudges" to guide patient choices (e.g., default referrals to CHCs unless a tertiary hospital is explicitly requested). Network Science: Map referral patterns using social network analysis to identify bottlenecks and key influencers in rehabilitation systems. Non-Cooperative Equilibrium: Institutions rationally pursue self-interest (e.g., resource hoarding), but this leads to system-wide inefficiencies (e.g., 65% of rehabilitation patients in Yanta still bypass CHCs) (Zhong et al., 2023). Cooperative Equilibrium: By internalizing externalities (e.g., sharing data reduces readmissions), institutions can achieve Pareto improvements. For example, Yanta's telerehabilitation network cut referral delays by 40% (Spruijt-Metz et al., 2015).

5 CONCLUSION

5.1 Key Findings

Game theory insights highlight the current non-cooperative iterated Prisoner's Dilemma with institutional memory, where resource hoarding and referral bottlenecks persist, and emphasize

cooperative solutions like coalition-building (e.g., CHCs specializing in post-acute care) to achieve Pareto improvements. Empirical support from Yanta District's pilots shows that policy adjustments and technological tools can mitigate these issues. This underscores the need for systemic reforms to transform fragmented, competitive dynamics into a collaborative, efficient rehabilitation ecosystem.

5.2 Research Significance

This study addresses critical inefficiencies in hierarchical medical systems by analyzing strategic interactions (game behavior) among sports rehabilitation institutions, offering both theoretical and practical contributions. The research highlights how non-cooperative dynamics—such as resource hoarding by tertiary hospitals, underinvestment in community health centers (CHCs), and information withholding—create systemic bottlenecks, undermining rehabilitation service accessibility and efficiency (e.g., 40% bed underutilization in Yanta District and 65% bypass of CHCs for rehabilitation care). By framing these challenges through game theory, the analysis reveals a "Prisoner's Dilemma" equilibrium where individual rationality leads to suboptimal collective outcomes, underscoring the need for institutional interventions to foster cooperation.

5.3 Limitations and Future Study

While this analysis provides a robust framework for addressing game behavior in sports rehabilitation under hierarchical systems, several limitations merit consideration. First, the empirical evidence is primarily drawn from pilot programs in Yanta District and Shaanxi Province, potentially limiting generalizability to contexts with different healthcare financing structures, administrative capacities, or regional demographics (e.g., rural vs. urban disparities varying levels of technological infrastructure). Second, the game theory model simplifies institutional interactions as a binary Prisoner's Dilemma, which may overlook more nuanced strategic dynamics, such as repeated interactions, multi-party coalitions, or the influence of informal relationships between institutions, which could alter cooperation incentives. Third, the study focuses on supply-side behaviors (institutions' resource allocation and referral decisions) but does not fully explore demand-side factors, such as patient preferences for tertiary hospitals or literacy levels affecting the utilization of CHC services, which might moderate the effectiveness of proposed solutions. Additionally, the long-term sustainability of interventions like tiered reimbursements or centralized EHR systems is not fully addressed, including potential fiscal burdens on healthcare budgets or resistance from stakeholders (e.g., tertiary hospitals losing revenue from retained patients). Finally, while technological tools (e.g., telerehabilitation platforms) are highlighted, the analysis does not account for digital divides or training gaps that could impede adoption, particularly in less-resourced settings. These limitations suggest a need for further research to validate findings in diverse contexts and incorporate broader systemic and behavioral factors into future models.

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