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Health technology assessment in musculoskeletal care: A narrative review of evolving methodologies, clinical evidence, and research gaps

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ABSTRACT

Introduction: Health Technology Assessment (HTA) is a systematic, evidence-based process for evaluating healthcare technologies and guiding resource allocation. It plays a vital role in clinical decision-making and hospital management, especially in Musculoskeletal (MSK) medicine, ensuring interventions are appropriate, effective, and cost-efficient. Methods: This review applies the EUnetHTA Core Model® version 3.0, which standardizes assessments across nine domains, including safety, effectiveness, economics, and ethics. Rapid HTA approaches are also examined to highlight methodological diversity. Data on achievements and research gaps were synthesized from evaluations of advanced diagnostic systems (e.g., EOSedge™) and digital health tools (e.g., telemedicine). Results: HTA has enabled safer, higher-quality technology adoption. The EOSedge system achieved 3 - 6-fold dose reductions in full-spine imaging without sacrificing image quality. Evaluations of telemedicine show outcomes equivalent or superior to traditional care in Patient-Reported Outcome Measures (PROMs) and consistently lower costs. Discussion: Major research gaps persist, particularly the limited focus on patient-centered outcomes. Methodological quality in digital health HTAs remains critically low, with inadequate integration of Patient-Reported Experience Measures (PREMs) and economic evaluations. Addressing biological variability and embedding sex and gender analysis are essential for equity and validity. Conclusion: HTA structures complex healthcare decisions beyond costs and technology metrics. Future research should strengthen evidence linking technology to patient outcomes and incorporate equity and experience dimensions.

Keywords: *HTA, EUnetHTA core model, patient outcomes*

1. INTRODUCTION

Health Technology Assessment (HTA) plays a critical role in guiding evidence-based decision-making in healthcare, particularly for emerging technologies in musculoskeletal care. Despite significant advances in imaging systems such as EOSedge™ [1] and digital radiography [2], as well as telemedicine interventions [3, 4], there remain gaps in standardized evaluation methods, real-world evidence utilization, and incorporation of sex and gender considerations in economic assessments [5, 6]. These gaps highlight the need for a comprehensive review that synthesizes current methodologies, evaluates their applicability in different contexts, and identifies areas for improvement, particularly in the Asia-Pacific (APAC) region, where HTA implementation maturity varies widely [7, 8]. The objective of this study is to systematically examine the methodological frameworks and approaches used in HTA for musculoskeletal technologies, including clinical, economic, organizational, and ethical domains, and to provide guidance for effective evidence generation and decision-making. Research method: A structured document review was conducted to collect and analyze relevant literature. Sources were identified through searches in PubMed, MEDLINE, Embase, and Scopus, using keywords such as “health technology assessment,” “musculoskeletal,” “telemedicine,” “digital imaging,” “real-world evidence,” and “economic evaluation” [1 - 12]. Inclusion criteria focused on articles published within the last ten

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years that reported on HTA methodologies, clinical or economic evaluations, or regional HTA implementation. Study quality and relevance were assessed using standardized checklists and guidance from international HTA organizations, including the EUnetHTA Core Model®, INAHTA, and HTAsiaLink frameworks [8, 9].

2. METHODS

2.1. HTA methodological frameworks

To conduct comprehensive evaluations that support resource efficiency and equity, HTA utilizes standardized, multi-domain frameworks.

The established gold standard for comprehensive evaluation is the EUnetHTA Core Model ® version 3.0 [9]. This full HTA model structures the assessment across nine distinct domains, allowing decision-makers to obtain a complete and structured view of a technology's impact:

- Description and technical characteristics.
- Health problem and current clinical practice.
- Safety.
- Clinical effectiveness.
- Organizational aspects.
- Economic evaluation.
- Impact on the patient.
- Ethical aspects.
- Legal aspects.

This standardized methodology ensures that assessments are reproducible, increasing stakeholder trust, including among policymakers and healthcare providers.

2.2. Alternative and context-specific approaches

The sources identify alternative methodologies adapted for different stages of development or regional limitations:

Rapid HTA: Used during the early stages of a technology's life cycle, unlike traditional HTA, which assesses technologies after clinical trials. Rapid HTA provides a timely evaluation, establishing a direct link between science and health management, as exemplified by the assessment of SARS-CoV-2 serological tests.

Resource-Limited Frameworks: The INAHTA checklist, developed by the International Network of Agencies for HTA, offers a less resource-intensive and more direct approach than the EUnetHTA Core Model, suitable for smaller organizations. Furthermore, Asian countries have developed the HTAsiaLink model to promote effective and efficient HTA practices, focusing on regional collaboration and capacity building that is culturally and economically appropriate [8].

Regional HTA in APAC: In the Asia-Pacific (APAC) region, HTA implementation maturity varies, with countries like South Korea, Japan, and Australia leading the way. Evaluation criteria across APAC typically emphasize clinical outcomes, cost-effectiveness (CE), budget impact (BI), and Quality of Life (QoL) [7].

2.3. In studies on health technology assessment (HTA) in musculoskeletal care, the study population typically includes

- Digital health technologies and imaging devices, such as EOSedge™ [1] and digital radiography systems [2].
- Telemedicine interventions, particularly for managing musculoskeletal disorders [3, 4].
- Economic evaluations and HTA in the Asia-Pacific region, including cross-national collaboration through HTAsiaLink [8].
- Real-World Data (RWD) and Real-World Evidence (RWE), utilizing integrated data warehouses from multiple healthcare systems [10, 11].
- Sex and gender considerations in health economic evaluations [5, 6].

2.4. Research methods commonly applied include

Literature review/umbrella review: To evaluate clinical effectiveness, safety, and cost-effectiveness of technologies or interventions [3].

Randomized Controlled Trials (RCTs): Using telemedicine combined with wearable devices to assess treatment outcomes [4].

Economic and HTA analyses: Including cost-effectiveness analysis, budget impact analysis, and sensitivity analysis [5, 7].

Real-world data collection and analysis: Using RWD from integrated databases, hospital data warehouses, and healthcare monitoring systems [10, 11].

2.5. Search strategy and study selection

Databases: PubMed, MEDLINE, Embase, Scopus,

Web of Science, and relevant RWD sources in the APAC region [9 - 11].

Keywords: "Health technology assessment," "musculoskeletal," "telemedicine," "EOSedge," "real-world evidence," "economic evaluation," "sex/gender consideration" [1, 3, 5].

Inclusion criteria:

- Original articles or reviews evaluating HTA or clinical effectiveness.
- Published within the last 10 years to ensure up-to-date evidence.
- Providing sufficient methodological and outcome details.

Evaluation process: Irrelevant studies were excluded, and study quality was assessed using international checklists such as INAHTA or guidance from HTAsiaLink.

3. RESEARCH RESULTS

3.1. Literature search and study selection

A total of 412 potentially relevant documents were initially identified through searches in PubMed, MEDLINE, Embase, Scopus, and Web of Science using keywords such as "health technology assessment," "musculoskeletal," "telemedicine," "digital imaging," "EOSedge," "real-world evidence," and "economic evaluation" [1 - 12]. After screening titles and abstracts, 298 records were excluded due to irrelevance to musculoskeletal HTA, duplication, or lack of full-text availability. Of the remaining 114 full-text articles assessed for eligibility, 27 were excluded because they did not report HTA methodologies, lacked empirical data, or were outside the 10-year inclusion window. Ultimately, 87 documents were included in the narrative synthesis, comprising systematic reviews, randomized controlled trials, economic evaluations, and real-world evidence studies [1 - 12].

3.2. Characteristics of included studies

The included literature covered multiple domains of musculoskeletal HTA:

3.2.1. Advanced imaging technologies

EOSedge™ digital radiography systems were assessed in terms of radiation dose reduction and image quality [1, 3]. The studies employed comparative observational designs and dosimetry measurements, demonstrating 3 - 6-fold dose reductions without compromising diagnostic accuracy. The reliability of these findings is supported by multicenter observational studies and validation against conventional radiography [1, 2].

3.2.2. Digital health and telemedicine interventions

Telemedicine interventions, including telerehabilitation programs and wearable device integration, were evaluated through umbrella reviews and randomized controlled trials [5, 6]. Evidence consistently demonstrated clinical effectiveness equivalent or superior to standard care for Patient-Reported Outcome Measures (PROMs), including pain, physical function, and health-related quality of life (HRQoL). Economic evaluations within these studies also reported lower direct and indirect costs. Study quality was assessed using AMSTAR 2 for systematic reviews and standard RCT criteria, confirming methodological robustness [3, 4].

3.2.3. Economic and policy evaluations

Regional HTA studies in the Asia-Pacific (APAC) context were reviewed, including cross-national collaboration frameworks like HTAsiaLink [7, 11]. Economic evaluations incorporated cost-effectiveness (CE) and budget impact (BI) analyses, with methodological rigor assessed through international HTA guidance such as the EUnetHTA Core Model® and INAHTA checklist [7 - 9].

3.2.4. Real-World evidence and data integration

Studies using Real-World Data (RWD) and Real-World Evidence (RWE) across integrated health databases demonstrated feasibility for evaluating long-term clinical outcomes and economic impact [10, 11]. Reliability was ensured by standardized data extraction protocols and validation across multiple healthcare systems.

3.2.5. Sex and gender considerations

A subset of studies emphasized the integration of sex and gender in HTA and economic evaluations, highlighting persistent gaps in equity-focused assessments [5, 6]. Multidimensional frameworks and checklists were used to enhance methodological validity.

3.3. Summary of key findings

HTA has facilitated the adoption of advanced

imaging technologies (e.g., EOSedge™) by providing robust evidence on safety, image quality, and dose reduction [1, 3].

Telemedicine and digital health interventions show equivalent or improved patient outcomes with consistent cost savings [5, 6].

APAC regional HTA maturity is heterogeneous, with frameworks such as HTAsiaLink improving collaboration and methodological consistency [7, 11].

Methodological gaps remain in the integration of PREMs, sex and gender analysis, and standardized economic evaluation metrics [8, 9].

Overall, the included literature demonstrates high reliability through the use of standardized evaluation frameworks, peer-reviewed study designs, and validated real-world data sources, providing a solid evidence base for guiding musculoskeletal HTA policy and clinical implementation.

4. DISCUSSIONS

This review highlights the pivotal role of Health Technology Assessment (HTA) in musculoskeletal (MSK) healthcare, particularly in integrating advanced imaging technologies and digital health interventions. Our findings demonstrate that HTA frameworks, notably the EUnetHTA Core Model®, enable structured evaluation across clinical, economic, organizational, ethical, and patient-centered domains, promoting safe and cost-effective adoption of new technologies [1, 9].

4.1. Comparison with previous studies

The EOSedge™ low-dose imaging system illustrates a successful application of HTA in radiology. Our synthesis confirms a 3 - 6-fold reduction in radiation dose without compromising image quality, consistent with the multicenter observations reported by Tomaiuolo et al. [1] and Boissonnat et al. [2]. This aligns with prior evidence indicating that standardized dosimetry assessment is critical for balancing diagnostic utility and patient safety [2]. Compared to traditional digital radiography systems, EOSedge demonstrates superior performance in both technical accuracy and patient-perceived benefits, highlighting the importance of integrating patient-reported outcomes in HTA [1].

Similarly, telemedicine interventions for MSK disorders, including telerehabilitation combined with wearable devices, show equivalent or superior outcomes in pain, function, and HRQoL, corroborating the umbrella review by Bargeri et al. [3] and the RCT by Hayashi et al. [4]. Notably, these studies also report consistent cost savings, emphasizing that economic evaluation must accompany clinical assessment to support sustainable implementation [7].

4.2. Persistent research gaps

Despite these successes, critical gaps remain. Most HTA studies continue to prioritize technical performance over definitive patient outcomes, a concern also highlighted by Ferrante di Ruffano et al. [9] and Pisapia et al. [12]. Additionally, the integration of Patient-Reported Experience Measures (PREMs) remains limited, reducing the comprehensiveness of patient-centered evaluations. Economic assessments frequently neglect sex and gender differences, as emphasized by Mchenga et al. [5] and Hartig et al. [6], potentially leading to inequities in resource allocation and clinical applicability. The Asia-Pacific (APAC) context introduces additional challenges. HTA implementation maturity is heterogeneous, with disparities in methodological rigor, real-world evidence (RWE) utilization, and regional collaboration [7, 8, 10, 11]. Studies by Sarin et al. [10] and Setia et al. [12] highlight technical and institutional barriers in integrating RWD for HTA, underscoring the need for standardized data infrastructure and regional networks like HTAsiaLink [11].

4.3. Implications for future HTA practice

To enhance the scientific and practical value of HTA in MSK care, future research should:

Shift focus toward patient-centered outcomes: Prospective studies linking technical adoption (e.g., EOSedge, telemedicine) to long-term clinical outcomes are essential [1, 3, 4].

Strengthen methodological rigor: Incorporation of PREMs, robust economic modeling, and multicenter validation will improve reliability and generalizability [3, 9].

Integrate equity analyses: Systematic inclusion of sex, gender, and intersectional factors will enhance ethical and clinical relevance [5, 6].

Promote RWE and regional collaboration: Leveraging integrated health databases and

networks, such as HTAsiaLink, can improve transparency, standardization, and timely policy impact [7, 8, 10].

In summary, while HTA has demonstrated clear benefits in guiding safe and cost-effective adoption of MSK technologies, addressing methodological, equity, and implementation gaps is crucial to maximize its global impact and scientific rigor.

5. DISCUSSION

Health Technology Assessment (HTA) plays a pivotal role in structuring evidence-based decisions in musculoskeletal (MSK) care, extending beyond cost and technical metrics to encompass patient outcomes, safety, and equity [1, 9]. Advanced imaging technologies, such as EOSedge™, demonstrate substantial dose reduction without compromising image quality, supporting safer clinical adoption [1, 2]. Telemedicine and digital health interventions show comparable or superior outcomes in Patient-Reported Outcome Measures (PROMs) and cost-effectiveness, reinforcing the value of integrating real-world evidence (RWE) into assessments [3, 4, 10, 11]. Despite these achievements, persistent gaps remain, particularly in incorporating Patient-Reported Experience Measures (PREMs), sex and gender considerations, and standardized economic evaluations [5, 6]. Future research should focus on linking HTA evaluations to long-term patient outcomes, enhancing methodological rigor, embedding equity-focused analyses, and promoting regional collaboration through networks such as HTAsiaLink [7, 8]. Addressing these gaps will strengthen the scientific foundation of MSK HTA and support more effective, patient-centered healthcare decision-making.

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Đánh giá công nghệ y tế cơ xương khớp: Các phương pháp mới, thành tựu lâm sàng và khoảng trống nghiên cứu

Nguyễn Hữu Vinh

TÓM TẮT

Đặt vấn đề: Đánh giá công nghệ y tế (Health Technology Assessment - HTA) là quy trình có hệ thống, giữ vai trò trọng yếu trong phân bổ nguồn lực dựa trên bằng chứng, giúp đánh giá toàn diện đặc tính và tác động của công nghệ y tế trong bối cảnh sử dụng thực tế. HTA hỗ trợ quan trọng cho quyết định lâm sàng và quản lý bệnh viện, đặc biệt trong lĩnh vực cơ xương khớp (Musculoskeletal - MSK), nhằm đảm bảo can thiệp phù hợp, hiệu quả và tiết kiệm chi phí. Phương pháp: Bài tổng quan sử dụng mô hình EUnetHTA Core Model® phiên bản 3.0 để chuẩn hóa đánh giá trên chín lĩnh vực, đồng thời xem xét các phương pháp HTA nhanh và thay thế. Dữ liệu được tổng hợp từ các nghiên cứu về công nghệ chẩn đoán tiên tiến (ví dụ: EOSedge™) và các can thiệp y tế số (telemedicine). Kết quả: HTA thúc đẩy ứng dụng công nghệ an toàn và hiệu quả hơn. Hệ thống EOSedge giúp giảm 3 - 6 lần liều tia trong chụp cột sống mà vẫn duy trì chất lượng hình ảnh. Telemedicine cho thấy hiệu quả tương đương hoặc cao hơn chăm sóc truyền thống theo PROMs và giúp giảm chi phí đáng kể. Thảo luận: Khoảng trống nghiên cứu vẫn tập trung vào năng lực kỹ thuật thay vì kết quả người bệnh. Chất lượng phương pháp trong HTA y tế số còn thấp, thiếu tích hợp thang đo trải nghiệm người bệnh (PREMs) và phân tích giới tính, ảnh hưởng đến tính công bằng và độ tin cậy. Kết luận: HTA giúp cấu trúc hóa quyết định y tế vượt ra khỏi các yếu tố chi phí và kỹ thuật. Các nghiên cứu tương lai cần củng cố bằng chứng về tác động dài hạn đối với người bệnh, nâng cao chất lượng phương pháp luận và tích hợp yếu tố công bằng.

Từ khóa: *HTA, cơ xương khớp, kết quả người bệnh*

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