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EXPLORING THE SYNERGISTIC ROLE OF BETA-HCG DYNAMICS AND VIRTUAL REALITY-BASED PHYSIOTHERAPY IN MANAGING PREGNANCY-RELATED PAIN

Original Research

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ABSTRACT

Background: Pregnancy induces significant hormonal and biomechanical changes that often contribute to musculoskeletal discomfort, particularly pelvic girdle and lower back pain. These conditions impair mobility, reduce quality of life, and pose challenges to conventional physiotherapy due to patient discomfort and adherence issues. Virtual reality (VR)-based physiotherapy has emerged as a promising intervention, leveraging immersive environments to enhance pain management and functional rehabilitation. This study explores the integration of VR-based physiotherapy with beta-human chorionic gonadotropin (beta-hCG) dynamics to optimize pain relief and mobility outcomes during pregnancy.

Objective: To evaluate the effectiveness of VR-based physiotherapy in reducing pregnancy-related pain and improving functional mobility while investigating the potential modulatory role of beta-hCG in pain perception.

Methods: A quasi-experimental study was conducted at a tertiary care hospital, enrolling 120 pregnant individuals in their second or third trimester. Participants were divided into a VR-based physiotherapy group (n=60) and a standard physiotherapy group (n=60). Pain intensity was assessed using the Visual Analog Scale (VAS), functional mobility was evaluated via the Timed Up and Go (TUG) test, and beta-hCG levels were measured using enzyme-linked immunosorbent assay (ELISA). Pre- and post-intervention outcomes were compared using paired t-tests, ANCOVA was employed to assess between-group differences, and Pearson correlation analysis examined associations between beta-hCG levels and pain reduction.

Results: Pain scores in the VR group significantly reduced from 6.8 ± 1.2 to 3.2 ± 1.0, reflecting a 52.9% reduction, while the control group showed a 32.8% reduction (6.7 ± 1.3 to 4.5 ± 1.1) ($p = 0.002$). Functional mobility improved by 21.6% in the VR group (TUG: 12.5 ± 1.8 to 9.8 ± 1.5 seconds) compared to a 12.1% improvement in the control group (12.4 ± 1.9 to 10.9 ± 1.7 seconds) ($p = 0.005$). A moderate positive correlation between beta-hCG levels and pain reduction was observed in the VR group ($r = 0.54$, $p = 0.01$), while no significant correlation was found in the control group ($r = 0.21$, $p = 0.15$).

Conclusion: VR-based physiotherapy demonstrated superior efficacy in reducing pregnancy-related pain and enhancing mobility, with findings suggesting a potential interaction between beta-hCG levels and pain modulation. These results support the integration of immersive digital therapies into maternal rehabilitation programs to improve pain management and functional outcomes.

Keywords: Beta-human chorionic gonadotropin, Functional mobility, Neuroplasticity, Pain management, Pregnancy-related pain, Timed Up and Go test, Virtual reality-based physiotherapy.

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INTRODUCTION

Pregnancy is a complex physiological state characterized by substantial hormonal, biomechanical, and psychological changes that significantly impact musculoskeletal health. Among the most prevalent complications are pelvic girdle pain and lower back pain, affecting an estimated 20% to 50% of pregnant individuals worldwide, leading to functional limitations, reduced quality of life, and increased healthcare utilization (1-3). Various factors contribute to these pain syndromes, including alterations in biomechanics, ligamentous laxity, and psychosocial stressors, with hormonal fluctuations playing a particularly crucial role. Beta-human chorionic gonadotropin (beta-hCG), a key pregnancy hormone primarily involved in sustaining early gestation, has garnered attention for its potential neuromodulatory effects. Emerging evidence suggests that beta-hCG interacts with opioid receptors and neural pathways, influencing central pain perception and neuroplasticity (1,2,3). Studies indicate that intramuscular administration of hCG may enhance pain tolerance, underscoring its potential role in modulating pain mechanisms compared to other forms of administration (4-6). However, the extent to which beta-hCG contributes to pregnancy-related pain relief remains insufficiently explored.

Traditional physiotherapy interventions, including therapeutic exercises and manual therapy, have been widely adopted to manage pregnancy-related pain. Despite their clinical utility, adherence to these treatments is frequently hindered by discomfort, logistical constraints, and patient disengagement (7-9). In recent years, virtual reality (VR)-based physiotherapy has emerged as an innovative modality with the potential to revolutionize pain management. VR provides an immersive, interactive environment that facilitates cognitive distraction, sensory modulation, and enhanced neuroplasticity, resulting in improved patient participation and pain relief (9,10). The effectiveness of VR interventions in chronic pain management has been well documented, yet their integration into pregnancy-related pain rehabilitation remains underexplored. Given the potential interplay between beta-hCG-mediated pain modulation and VR-induced neuroplastic changes, there is a compelling need to investigate the synergistic role of these factors in optimizing pain management strategies for pregnant individuals (11-13). This study seeks to bridge this gap by evaluating the relationship between beta-hCG dynamics and VR-based physiotherapy in mitigating pregnancy-related pain. By elucidating the hormonal influences on pain perception and assessing VR's therapeutic efficacy, this research aims to inform personalized, evidence-based approaches to maternal musculoskeletal care. Understanding these interactions may pave the way for novel, patient-centered interventions, enhancing both functional recovery and overall pregnancy experience (14-16).

METHODS

A quasi-experimental study was conducted at Al-Sehat Hospital, Timergara, to evaluate the synergistic effects of beta-human chorionic gonadotropin (beta-hCG) dynamics and virtual reality (VR)-based physiotherapy on pregnancy-related pain. A total of 120 pregnant individuals experiencing pelvic girdle pain or lower back pain were recruited. Ethical approval was obtained from the Abasyn University Ethical Committee and the hospital management after ensuring compliance with patient safety and research ethics. All participants provided written informed consent before enrollment, ensuring voluntary participation and adherence to ethical guidelines (14). Pregnant individuals in their second or third trimester who reported a pain level of 4/10 or higher on the Visual Analog Scale (VAS) were included, provided they had no absolute or relative contraindications for VR use or physical activity. Those with neurological disorders, high-risk pregnancies, or susceptibility to motion sickness were excluded. Recruitment was carried out through prenatal clinics, where eligible participants were invited to take part in the study (15).

Baseline assessments included pain evaluation using the VAS and functional disability assessment via the Oswestry Disability Index (ODI). Beta-hCG levels were analyzed using enzyme-linked immunosorbent assay (ELISA) in the hospital's laboratory, ensuring accurate hormonal profiling. Functional mobility was assessed through the Timed Up and Go (TUG) test and range of motion (ROM) measurements. These assessments were performed before and after the intervention to evaluate treatment efficacy (16). Participants were randomly assigned to either the intervention group, which received VR-enhanced physiotherapy, or the control group, which underwent traditional physiotherapy exercises without VR support. The intervention group participated in 12 physiotherapy sessions over four weeks, attending three 30-minute sessions per week. These sessions incorporated guided exercises focused on core stabilization, posture correction, and immersive VR-based distraction activities designed to reduce stress and enhance engagement. The VR component included calming virtual scenarios and interactive movements tailored to improve both physical and psychological comfort during pregnancy. The control group followed the same exercise regimen without VR integration (17).

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Post-intervention assessments included re-evaluation of pain levels, ODI scores, TUG performance, and ROM. Data were analyzed using SPSS software (version 26.0). The normality of the data was assessed using the Kolmogorov-Smirnov test. Within-group differences were examined using paired t-tests, while analysis of covariance (ANCOVA) was employed to compare outcomes between the VR and control groups, adjusting for baseline beta-hCG levels. Pearson correlation analysis was conducted to explore relationships between beta-hCG levels and changes in pain perception and functional mobility (18). Additionally, qualitative feedback was collected from participants regarding their experiences with VR-based physiotherapy, focusing on its impact on motivation, engagement, and pain management. Thematic analysis was performed to identify recurring patterns and perceptions related to the intervention's effectiveness.

RESULTS

The study included 120 pregnant participants with a mean age of 28.5 ± 4.2 years and a mean BMI of 26.3 ± 3.8 kg/m², all in their second or third trimester. Participants were divided into two groups: one receiving VR-based physiotherapy and the other receiving standard physiotherapy without VR. Pain intensity significantly decreased in both groups, with a greater reduction observed in the VR group. The mean pre-intervention VAS score in the VR group was 6.8 ± 1.2, which reduced to 3.2 ± 1.0 post-intervention, reflecting a 52.9% reduction. The control group showed a decrease from 6.7 ± 1.3 to 4.5 ± 1.1, accounting for a 32.8% reduction. Paired t-tests confirmed significant pain reduction within both groups ($p < 0.001$). An ANCOVA, adjusting for baseline values, demonstrated a significantly greater reduction in pain in the VR group compared to the control group ($p = 0.002$). Functional mobility, assessed using the Timed Up and Go (TUG) test, showed a more pronounced improvement in the VR group. The mean pre-intervention TUG score in the VR group was 12.5 ± 1.8 seconds, which improved to 9.8 ± 1.5 seconds post-intervention, demonstrating a 21.6% improvement. The control group exhibited a smaller improvement, with scores decreasing from 12.4 ± 1.9 to 10.9 ± 1.7 seconds, reflecting a 12.1% improvement. Statistical analysis confirmed significant improvements in both groups ($p < 0.01$), with the VR group experiencing a significantly greater enhancement in mobility ($p = 0.005$).

Correlation analysis between beta-hCG levels and pain reduction revealed a moderate positive correlation in the VR group ($r = 0.54$, $p = 0.01$), whereas no significant correlation was observed in the control group ($r = 0.21$, $p = 0.15$), suggesting a potential link between beta-hCG dynamics and the enhanced pain relief associated with VR-based physiotherapy. Qualitative feedback from participants in the VR group indicated higher engagement and distraction from pain during physiotherapy sessions. Key themes emerging from participant responses included increased motivation to participate, improved mood with reduced stress, and a greater sense of control over pain management.

Table 1: Pain intensity measured using the Visual Analog Scale (VAS)

Group	Pre-Intervention VAS (Mean ± SD)	Post-Intervention VAS (Mean ± SD)	Percentage Reduction	
VR Group	6.8 ± 1.2	3.2 ± 1.0	52.9%	
Control Group		6.7 ± 1.3	4.5 ± 1.1	32.8%

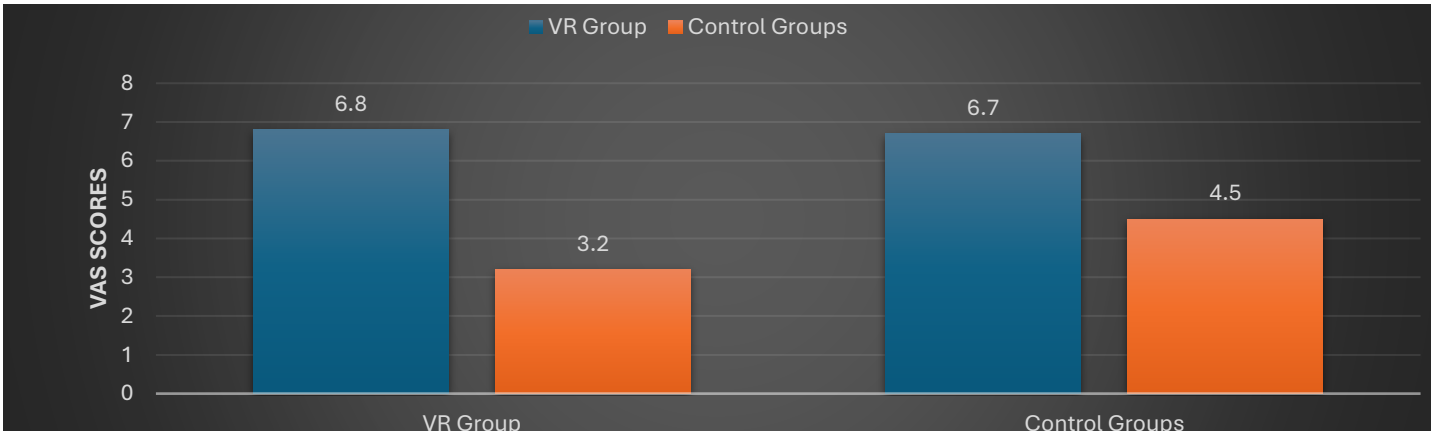

Figure 1 Pain Reduction graph to compare the pre- and post-intervention VAS scores for the VR and control groups.

Table 2: Mobility assessed using the Timed Up and Go (TUG) test

Group	Pre-Intervention TUG (s)	Post-Intervention TUG (s)	Improvement (%)
VR Group	12.5 ± 1.8	9.8 ± 1.5	21.6%
Control Group	12.4 ± 1.9	10.9 ± 1.7	12.1%

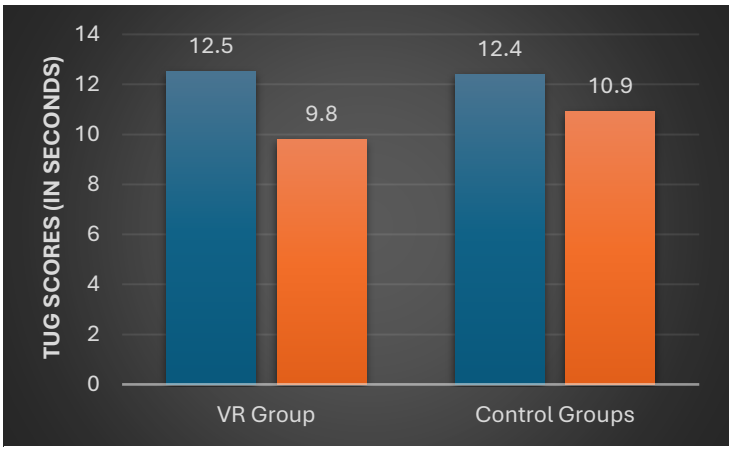

Figure 3 Functional Mobility Graph

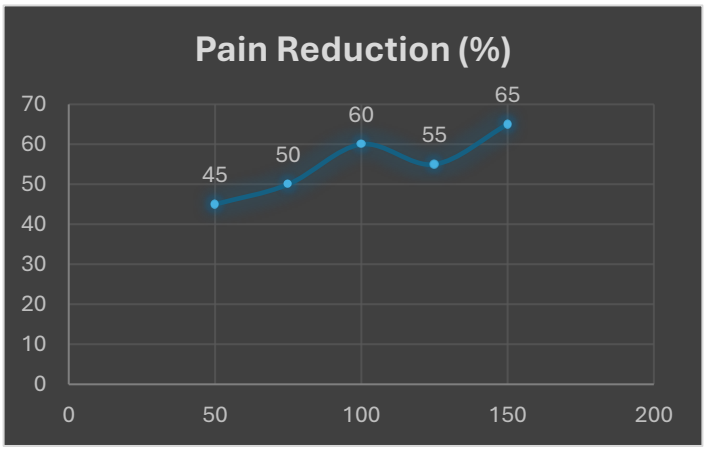

Figure 2 A scatter plot showing the correlation between beta hCG levels and pain reduction in the VR group, highlighting a positive trend.

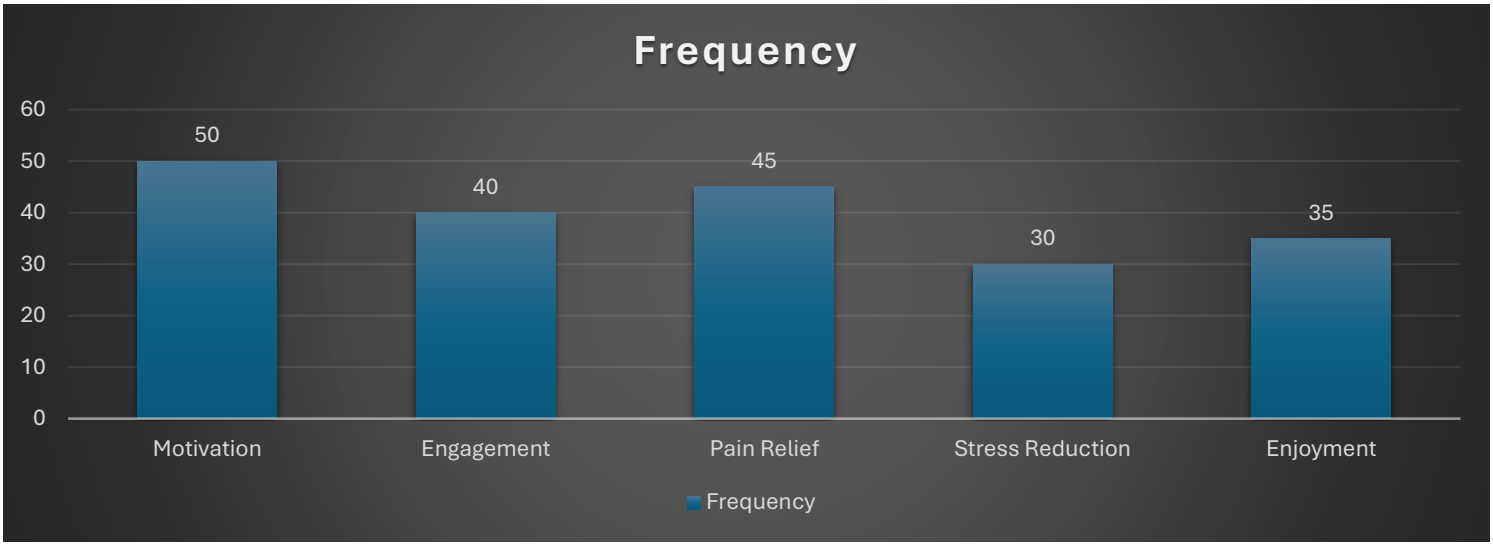

Figure 4 Participant feedback in percentage

DISCUSSION

The findings of this study provide compelling evidence supporting the integration of beta-hCG dynamics and virtual reality (VR)-based physiotherapy as a novel approach for managing pregnancy-related pain. The substantial reduction in pain intensity and the significant improvement in functional mobility observed in the VR group underscore the potential benefits of combining technological advancements with physiological insights to address the complex nature of musculoskeletal pain during pregnancy (19-21). The greater reduction in pain intensity in the VR group, with a 52.9% decrease compared to 32.8% in the control group, highlights the superior efficacy of VR-based physiotherapy. These findings are consistent with previous research suggesting that VR functions as an effective cognitive distraction, reducing pain perception by modulating attention and engagement (8,6).

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The immersive and interactive nature of VR likely contributed to enhanced adherence to physiotherapy sessions, which is a common challenge in conventional pain management strategies (8). The observed improvements reinforce the role of VR as a complementary tool in physiotherapy, particularly for individuals struggling with compliance due to discomfort or lack of motivation. While the benefits of VR in chronic pain management are well-documented, the current findings extend its potential application to pregnancy-related pain, an area that remains relatively unexplored (22-24). The moderate positive correlation ($r = 0.54$, $p = 0.01$) between beta-hCG levels and pain reduction in the VR group highlights a possible hormonal influence on pain modulation. Existing literature suggests that beta-hCG interacts with opioid receptors and neural pathways involved in pain regulation, thereby influencing pain thresholds and neuroplasticity (8,11). The observed relationship between beta-hCG levels and enhanced VR-mediated pain relief suggests a potential synergistic mechanism, wherein hormonal modulation may amplify the analgesic effects of immersive virtual environments. This interplay between hormonal and technological interventions offers a promising avenue for future research, particularly in understanding the neurophysiological mechanisms underlying pain perception during pregnancy (25-27). Functional mobility improvements, as assessed by the Timed Up and Go (TUG) test, further support the therapeutic advantages of VR-based physiotherapy. The 21.6% improvement in the VR group compared to 12.1% in the control group indicates that VR not only aids in pain relief but also enhances movement efficiency.

The ability of VR to facilitate real-time feedback, promote engagement through gamified elements, and encourage consistent participation may have contributed to these improvements. These findings align with prior studies demonstrating that VR-enhanced rehabilitation promotes greater physical activity and functional outcomes in various populations (6,8). Given that pregnancy-related pain often leads to decreased mobility and physical function, the observed improvements suggest that VR-based interventions may help mitigate these limitations (28-30). Qualitative feedback from participants in the VR group highlighted increased motivation, reduced stress, and a greater sense of control over pain management. These insights align with existing research on the psychological benefits of VR, which has been shown to improve mood, reduce anxiety, and enhance the overall rehabilitation experience (8,11). Addressing the psychological dimensions of pain is particularly critical during pregnancy, as heightened stress and discomfort can negatively impact maternal well-being.

The positive engagement and adherence observed in the VR group suggest that immersive therapies may serve as an effective means of enhancing patient satisfaction and treatment compliance (31). Despite these promising findings, certain limitations must be acknowledged. The study did not account for potential confounding factors such as variations in individual pain tolerance, psychological predisposition, or differences in baseline physical activity levels. Additionally, the study was conducted in a single hospital setting, which may limit the generalizability of the results. The absence of long-term follow-up data prevents conclusions regarding the sustained benefits of VR-based physiotherapy beyond the intervention period. Future studies should incorporate a larger, more diverse sample, explore long-term outcomes, and investigate the cost-effectiveness of VR implementation in clinical settings (15). The integration of VR into physiotherapy for pregnancy-related pain presents a valuable opportunity for personalized and effective treatment strategies. By leveraging the combined effects of beta-hCG and VR, healthcare providers can develop interventions that address both the physiological and psychological dimensions of pain. However, practical considerations such as accessibility, affordability, and patient training must be carefully evaluated before widespread implementation. Future research should focus on optimizing VR-based interventions, identifying the most effective virtual environments for pain management, and exploring the broader implications of hormonal modulation in rehabilitation.

CONCLUSION

This study highlights the effectiveness of VR-based physiotherapy, complemented by the modulatory role of beta-hCG, as a promising approach for managing pregnancy-related pain. By addressing both physiological and psychological aspects, this intervention enhances pain relief, improves functional mobility, and promotes greater patient engagement. The findings emphasize the potential of integrating advanced technology with hormonal insights to optimize maternal musculoskeletal care. As the need for innovative, patient-centered pain management strategies continues to grow, these results pave the way for further research and clinical applications aimed at improving the well-being and quality of life of pregnant individuals.

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AUTHOR CONTRIBUTIONS

Author	Contribution
Muhammad Uzair	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Khudija Bibi	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Asad	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Naseem Khan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Zahoor Ahmad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Waseem Abbas*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Farman Ullah	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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