IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

BIOFEEDBACK BASED GAMIFICATION IN REHABILITATION OF DISTAL RADIUS AND ULNAR FRACTURE: A CASE REPORT

[1]Bismay Kumar Sethy, [2]Ritu Patwari

[1]Consultant Physiotherapist, [2]Assistant Professor

[1]Physiotherapy,

[1]Advanced Rehabilitation Centre, Baripada, Odisha, India

ABSTRACT

Background: Distal radius and ulnar fractures are among the most common traumatic injuries, often requiring comprehensive rehabilitation to restore optimal function. Advances in rehabilitation technologies have introduced biofeedback-based gamification as a promising adjunct to conventional physiotherapy.

Objective: This case report explores the therapeutic efficacy of a four-week biofeedback-based gamification intervention, delivered through the Virtual Reality Rehabilitation System (VRRS, Khymeia, Italy), along with a supervised exercise programme in the rehabilitation of a patient with a complex distal radius and ulnar fracture.

Methods: A 38-year-old male with a history of closed comminuted fractures involving the distal radius, mid-shaft ulna, and elbow joint underwent a structured rehabilitation protocol incorporating Biofeedback-based gamification exercises and a supervised exercise programme. Outcomes were assessed using active range of motion (measured with inertia sensors), grip strength (measured with a K-force sensor), and functional ability (as indicated by the QuickDASH score).

Results: Post-intervention outcomes demonstrated significant improvements: elbow flexion increased from 75.34° to 82.75°, pronation from 23.57° to 54.15°, and supination from 14.92° to 39.85°. Grip strength improved from 2.03 kg to 7.98 kg, and the Quick DASH score reduced from 45.45 to 38.63, indicating enhanced functional independence and reduced disability.

Conclusion: The integration of biofeedback-based gamification through VRRS proved to be an effective adjunct in improving upper limb function, pain tolerance, and patient engagement. These findings support further exploration through larger randomized controlled trials to validate the clinical utility of gamification in post-traumatic musculoskeletal rehabilitation.

Keywords: Right (Rt.), Upper Extremity (UE), Outpatient Department (OPD), Range of Motion (ROM), Anterior (ant.), Virtual Reality Rehabilitation System (VRRS), Virtual Reality (VR), Activities of Daily Living (ADL)

INTRODUCTION:

Distal radius fractures are among the most common traumatic injuries, accounting for 18% of all fractures seen in emergency departments. They represent up to 25% of pediatric fractures and 18% of fractures in the elderly[1-3], with incidence rates of 30 per 10,000 person-years in those under 18 and 25 per 10,000 in those over 65 [4]. Among older adults, women are five times more likely to be affected than men. The incidence of these fractures is rising with the ageing population.[4-6]

Distal radius fractures can be treated surgically or non-surgically, with post-treatment rehabilitation often involving physiotherapy or hand therapy to restore function. While early exercise is generally agreed to be beneficial, current research is inconclusive on whether supervised physiotherapy is more effective than unsupervised home-based programs.[7-11]

Conventional physiotherapy techniques—such as cryotherapy, exercise balls, manual therapy, and electrotherapy—remain widely used.[12] However, advancements in science and technology have led to the integration of virtual and augmented reality into rehabilitation programs, particularly for musculoskeletal and neurological conditions, enhancing the scope and delivery of physiotherapy.[13]

Gamification, through the use of serious games, is an emerging approach in physiotherapy that employs game-based, goal-oriented, 3D immersive interfaces to enhance functional recovery, particularly in chronic musculoskeletal and neurological conditions[14]. Serious games typically use consumer-based consoles like the Nintendo Wii, which can support rehabilitation but require external hardware, limiting portability and accessibility[15]. A systematic review on serious games in traumatic injury rehabilitation identified only commercially available, console-based games, with no wearable-controlled options. Wearable sensor-based games, when integrated with mobile platforms, offer greater flexibility and may improve adherence by enabling patients to exercise anytime and anywhere.[16] However, there are few studies evaluating such biofeedback-based, wearable-controlled serious games for traumatic injuries.

CASE PRESENTATION:-

A 38-year-old male approached the physiotherapy outpatient department (OPD) for rehabilitation follow-up-case of a closed comminuted intra-articular fracture of the olecranon with a comminuted coronoid process fracture (Right side) closed displaced fracture mid-shaft ulna with dislocation of the radiohumeral joint (Right) side, closed comminuted fracture distal end of the radius (Right) 2 years back with history of fall from the stairs with an outstretched hand.

SURGICAL HISTORY

Open reduction + internal fixation with plate & K-wire fixation for the distal end of radius fracture on the right was done on **26/3/2023 (Figure 1a and 1b)**

Fig. 1a:- X-Ray Dated 29.03.2024

Fig. 1b:- X-Ray Dated 29.03.2024

Fig. 2:- X-Ray Dated 15.05.2025

- Implant removal was done under RA on **14/05/25, Figure 2**

The patient was referred to the physiotherapy OPD after 30 days of implant removal with chief complaints of Difficulty in using Rt. U/E for ADL activities, restricted ROM of Rt. elbow and wrist, decreased Rt—grip strength.

CLINICAL EVALUATION: -

On Observation: -

Body Built- Endomorphic

The attitude of the affected Limb shows the right. Shoulder depressed with scapular retraction and slightly abducted.

Rt. Elbow flexion (15-20^{0}) with the elbow in mid-prone position.

Right wrist neutral with fingers extended.

Swelling is present in the ant aspect of the forearm to the wrist joint.

A scar mark on the posterolateral aspect of Rt. Elbow jt and ant. Aspect of the Rt. Wrist. As shown in **Figure 3a and Figure 3b**

Fig. 3a

Fig. 3b

On Palpation:-

Tenderness present over the right wrist surgical scar was of Grade 2.

On Examination:

Pre-intervention ROM **Table 1** was measured using the Inertia Sensors (VRRS), **Figure 4**

Fig. 4: Inertia Sensors

Table 1 – Pre-intervention ROM

RT. ELBOW	Flexion [AROM]	Pronation [AROM]	Supination [AROM]
	25^{0}-75.34^{0}	0-23.57^{0}	0-14.92^{0}

- Superficial Sensation was intact on the affected hand.
- Pre-intervention Rt. Grip strength **2.03 kgs** noted using K-Grip sensor (VRRS), **Figure 5**
- Rt. U/L functional activities: Quick DASH was used. The pre-intervention score was **45.45 points.**

Fig. 5: K Force Grip Sensor

Therapeutic Intervention:-

Physiotherapy intervention based on biofeedback-based gamification was given to the patient, intended to increase ROM and Grip Strength for which Virtual Reality Rehabilitation System (VRRS) Company name-Khymeia, Italy Manufacturing year-2024 as shown in (**Figure 6)** was used along with that, a supervised exercise programme was given to the patient, which includes (Gel ball squeezing exercises, weight bearing in Quadruped, Scar tissue mobilisation exercises).

Fig. 6: VRRS (Khymeia, Italy)

Biofeedback-based AROM exercises

Biofeedback-based Gamification is sensor-based, which gives real-time feedback to the patient if there is any abnormal movement triggered by the patient that the sensors detect, and the visual and audio feedback corrects the patient. One inertia sensor (**S1**) is placed on the lateral aspect of the arm, and the sensor (**S2)** is placed over the lateral aspect of the wrist. **For example**, when the patient performs a ROM movement for elbow prono-supination, it detects any abnormal movement in the shoulder and, through visual and auditory feedback, corrects the patient. (**Figure7a and Figure7b)**

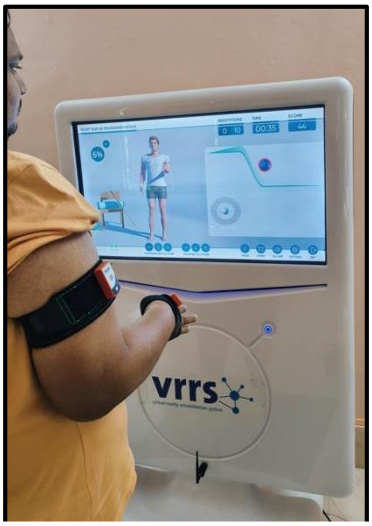

Fig. 7a- Biofeedback-based exercises for pronosupination movement

Fig. 7b- Biofeedback-based exercises for pronosupination movement

All otherwise necessary instructions are embedded within the game, making the game 'self-explanatory'. The patient plays 3 sets of 10 repetitions for approximately 15-20 minutes for each exercise. Every playing session starts with a 'warm-up' of the motions, during which the motion sensors are calibrated, and the game is set to the patients' own maximum ROM.

The game's levels can be gradually increased by increasing the compensation multiplier and decreasing the movement multiplier over 4 weeks. Motivation is further enhanced through optional high score rankings. The application tracks gameplay frequency, duration, scores and records rehabilitation progress by measuring range of motion (ROM) in degrees.

Grip Strengthening Exercises

For grip strengthening, we used a **K-force grip sensor (Figure 5**) based on gamification, which consists of different games based on a similar level of difficulty, such as **Palmar grip Catching exercises and Palmar grip Reaching exercises**. Every playing session starts with a 'warm-up' of the motions, during which the K-grip sensors are calibrated. The patient holds a K-force grip sensor between the palm and fingers, squeezes the sensor; the car avatar moves to collect the items every time the patient performs the exercise. (**Figure 8)**

Fig. 8- Patient squeezes the K-force Grip sensor to control the car and collect the items.

Supervised Exercise Program

Includes gel ball squeezing exercises for Proximal Interphalangeal joint and Distal Interphalangeal joint range of motion, Grip strengthening exercises, Scar tissue mobilisation and weight bearing in quadruped position.

RESULTS:-

After 4 weeks of Biofeedback-based gamification, patient progression was again recorded to determine the impact of gamification on range of motion, Grip strength, and hand function. The results showed significant improvement in all the outcomes. [**Table 2]**

Table 2 – Post-intervention ROM

Rt. elbow	Flexion [AROM]	PRONATION [AROM]	SUPINATION [AROM]
	0^0-82.75^0	0^0-54.15^0	0^0-39.85^0

- **Grip Strength** increased from **2.03 kgs to 7.98 kgs** post-treatment.
- Functional abilities using **Quick Dash** showed a decrease in score of 38.63 post-intervention after 4 weeks, which signifies less disability and less severity.

DISCUSSION:-

Gamification and serious games have emerged as promising tools in healthcare, particularly in rehabilitation. Deterding et al.[17,18] define **gamification** as the application of game design elements—such as points, badges, and leaderboards—in non-game contexts to enhance motivation and user engagement. Zhang et al [19] stated that "the gamification approaches used included the addition of gaming elements to existing tasks, transformation of a conventional task into a serious game."

Mack et al [20] refer to serious games as "games designed to fulfil a serious purpose by providing education from health professionals via a digital device." These are fully developed interactive games with a clear educational or therapeutic purpose, often employing narrative and immersive experiences to promote skill development and clinical outcomes.

The integration of these approaches into rehabilitation has demonstrated notable benefits. Gamification, by creating an engaging and interactive environment, encourages patients to exceed perceived pain thresholds and adhere more consistently to rehabilitation programs. Virtual reality (VR) games, a common format for serious games, have shown efficacy as adjunct tools in upper limb rehabilitation post-stroke, improving function and overall health status [Ahmad et al., 2019].[21] In neurological conditions such as Parkinson's disease, serious games and immersive VR technologies have been effective in enhancing coordination, dexterity, and motor performance [Sánchez-Herrera-Baeza et al., 2020].[22]

Additionally, studies have reported improvements in joint mobility, particularly in conditions like traumatic shoulder stiffness, through real-time virtual feedback interventions that enhance shoulder kinetics and kinematics [Schwartz et al., 2022].[23] In stroke rehabilitation, gamification has provided clinical advantages such as adjustable difficulty levels, standardised task progression, and safe, real-time simulation environments—all contributing to improved upper limb motor outcomes [Kim et al., 2020].[24]

Gamification has emerged as a powerful tool in enhancing patient engagement and compliance during rehabilitation, particularly in cases of distal radius fracture (DRF). By creating an immersive and interactive environment, gamified rehabilitation encourages patients to exceed their pain thresholds and engage more willingly in repetitive exercises, which are critical for recovery.[21] Studies, including one published by the DMIHER School of Epidemiology and Public Health (2022), have demonstrated that gamified environments significantly improve wrist and hand mobility in a shorter duration compared to conventional methods. The modulation of attention through gamification—via sensory precision control—facilitates better coordination and goal-directed action even under sensory conflict, such as pain or discomfort. Overall, gamification introduces an engaging, motivating, and neurobiologically grounded approach that significantly enhances rehabilitation outcomes in post-fracture recovery, which aligns with our results.[25]

Overall, gamification and serious games offer exciting potential in rehabilitation, but their success depends heavily on thoughtful implementation, clinical relevance, and rigorous validation. Future research should focus on large-scale, randomised controlled trials that not only evaluate clinical efficacy but also explore user experience, accessibility, and cost-effectiveness to support integration into standard care pathways.

CONCLUSION:-

This case report highlights the substantial improvements observed after four weeks of biofeedback-based gamification using the VRRS (Khymeia, Italy) system in a patient with distal radius fracture (DRF). Enhancements were noted in range of motion (ROM), grip strength, and functional independence. The integration of gamification effectively modulated the rehabilitation process and demonstrated significant therapeutic potential. These findings support the broader exploration of gamification as a rehabilitative tool for other traumatic musculoskeletal conditions. Future randomised controlled trials with larger sample sizes are warranted to validate the efficacy of gamification. As an adjunct to conventional rehabilitation, gamification may enhance patient engagement and compliance, opening new avenues in musculoskeletal recovery.

REFERENCES:-

1. Mellstrand-Navarro, C., Pettersson, H. J., Tornqvist, H., Ponzer, S., & Svensson, O. (2014). The operative treatment of fractures of the distal radius is increasing: Results from a nationwide Swedish study. *Bone & Joint Journal, 96*-B(7), 963–969.
2. Court-Brown, C. M., & Caesar, B. (2006). Epidemiology of adult fractures: A review. *Injury, 37*(8), 691–697.
3. Kilgore, M. L., Morrisey, M. A., Becker, D. J., et al. (2009). Health care expenditures associated with skeletal fractures among Medicare beneficiaries, 1999–2005. *Journal of Bone and Mineral Research, 24*(12), 2050–2055.
4. Nellans, K. W., Kowalski, E., & Chung, K. C. (2012). The epidemiology of distal radius fractures. *Hand Clinics, 28*(2), 113–125.
5. Karl, J. W., Olson, P. R., & Rosenwasser, M. P. (2015). The epidemiology of upper extremity fractures in the United States, 2009. *Journal of Orthopaedic Trauma, 29*(8), e242–e244.
6. MacIntyre, N. J., & Dewan, N. (2016). Epidemiology of distal radius fractures and factors predicting risk and prognosis. *Journal of Hand Therapy, 29*(2), 136–145.
7. Fricker, R., Jupiter, J., & Kastelec, M. (2017). *AO Surgery Reference: Distal forearm* [Internet]. Davos, Switzerland: AO Foundation.
8. Handoll, H. H. G., & Elliott, J. (2005). Rehabilitation for distal radial fractures in adults. *Cochrane Database of Systematic Reviews, 2005*(3), CD003324.
9. Bruder, A. M., Shields, N., Dodd, K. J., & Taylor, N. F. (2016). A progressive exercise and structured advice program does not improve activity more than structured advice alone following a distal radial fracture: A multi-centre, randomised trial. *Journal of Physiotherapy, 62*(3), 145–152.
10. Gutiérrez-Espinoza, H., Rubio-Oyarzún, D., Olguín-Huerta, C., et al. (2017). Supervised physical therapy vs home exercise program for patients with distal radius fracture: A single-blind randomized clinical study. *Journal of Hand Therapy, 30*(3), 242–252.
11. Krischak, G. D., Krasteva, A., Schneider, F., Gulkin, D., Gebhard, F., & Kramer, M. (2009). Physiotherapy after volar plating of wrist fractures is effective using a home exercise program. *Archives of Physical Medicine and Rehabilitation, 90*(4), 537–544.
12. Arrebola, L. S., Yi, L. C., & de Oliveira, V. G. (2019). The use of video games combined with conventional physical therapy in children with upper limb fractures: An exploratory study. *Journal of Pediatric Rehabilitation Medicine, 12*(1), 65–70.
13. Cha, K., Wang, J., Li, Y., Shen, L., Chen, Z., & Long, J. (2021). A novel upper-limb tracking system in a virtual environment for stroke rehabilitation. *Journal of NeuroEngineering and Rehabilitation, 18*, 166.
14. Warsinsky, S., Schmidt-Kraepelin, M., Rank, S., Thiebes, S., & Sunyaev, A. (2021). Conceptual ambiguity surrounding gamification and serious games in health care: Literature review and development of Game-Based Intervention Reporting Guidelines (GAMING). *Journal of Medical Internet Research, 23*(8), e30390.

15. Brichetto, G., Spallarossa, P., de Carvalho, M. L. L., Battaglia, M. A., Feraco, P., & Gualandi, F. (2013). The effect of Nintendo Wii on balance in people with multiple sclerosis: A pilot randomized control study. *Multiple Sclerosis, 19*(9), 1219–1221.
16. Meijer, H. A., Graafland, M., Goslings, J. C., & Schijven, M. P. (2018). Systematic review on the effects of serious games and wearable technology used in the rehabilitation of patients with traumatic bone and soft tissue injuries. *Archives of Physical Medicine and Rehabilitation, 99*(9), 1890–1899.
17. Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification." In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (pp. 9–15).
18. Deterding, S., Khaled, R., Nacke, L., & Dixon, D. (2011). Gamification: Toward a definition. In *CHI 2011 Gamification Workshop Proceedings*, Vancouver, BC, Canada.
19. Zhang, M., Ying, J., Song, G., Fung, D. S., & Smith, H. (2018). Gamified cognitive bias modification interventions for psychiatric disorders: Review. *JMIR Mental Health, 5*(4), e11640.
20. Mack, I., Reiband, N., Etges, C., Eichhorn, S., Schaeffeler, N., Zurstiege, G., et al. (2020). The Kids Obesity Prevention Program: Cluster randomized controlled trial to evaluate a serious game for the prevention and treatment of childhood obesity. *Journal of Medical Internet Research, 22*(4), e15725.
21. Ahmad, M. A., Singh, D. K., Mohd Nordin, N. A., Hooi Nee, K., & Ibrahim, N. (2019). Virtual reality games as an adjunct in improving upper limb function and general health among stroke survivors. *International Journal of Environmental Research and Public Health, 16*(24), 5144.
22. Sánchez-Herrera-Baeza, P., Cano-de-la-Cuerda, R., Oña-Simbaña, E. D., et al. (2020). The impact of a novel immersive virtual reality technology associated with serious games in Parkinson's disease patients on upper limb rehabilitation: A mixed methods intervention study. *Sensors, 20*(8), 2168.
23. Schwartz, I., Safran, O., Karniel, N., et al. (2022). Positive effect of manipulated virtual kinematic intervention in individuals with traumatic stiff shoulder: A pilot study. *Journal of Clinical Medicine, 11*(13), 3919.
24. Kim, W. S., Cho, S., Ku, J., Kim, Y., Lee, K., Hwang, H. J., & Paik, N. J. (2020). Clinical application of virtual reality for upper limb motor rehabilitation in stroke: Review of technologies and clinical evidence. *Journal of Clinical Medicine, 9*(10), 3369.
25. Limanowski, J., & Friston, K. (2020). Active inference under visuo-proprioceptive conflict: Simulation and empirical results. *Scientific Reports, 10*(1), 4010.