ORIGINAL ARTICLE

CONTENTS

Hand telerehabilitation for polytrauma patients following road traffic accidents

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ABSTRACT

Aim: This study aimed to examine the characteristics of upper limb and shoulder injuries combined with chest trauma in road accident victims and evaluate the effectiveness of telemedical monitoring and a newly developed telerehabilitation model in patient recovery.

Materials and Methods: Our study incorporated 136 medical records of inpatients who had sustained upper extremity and chest injuries, constituting a retrospective group. Additionally, in the main group, we included 73 patients with similar injuries of the upper extremity and chest.

Results: We analyze the functional results between the retrospective group and the main group, providing valuable insights into the effectiveness of traditional rehabilitation versus telerehabilitation. Focusing first on the average time spent on rehabilitation exercises per day, we observe a noticeable difference: while the retrospective group dedicated an average of 29±8 minutes daily, the main group invested more time, averaging 42±4 minutes. The retrospective group reported an average of 12±2 visits, in stark contrast to the main group, which averaged only 4±2 visits. The rehabilitators spent considerably less time with each patient in the main group (92±14 minutes) compared to the retrospective group (263±15 minutes), with a significant difference ($p<0.005$). The discovery in our study that there was no notable statistical difference in the functional outcomes, as evaluated by QuickDASH scores, between patients undergoing telerehabilitation and those receiving traditional rehabilitation is of significant importance.

Conclusions: The findings reveal that telerehabilitation can significantly increase patient engagement in rehabilitation exercises, primarily due to its convenience and accessibility.

KEY WORDS: telerehabilitation, polytrauma, upper limb, chest, road trauma

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INTRODUCTION

Injury remains a significant global health issue as it is associated with high morbidity and mortality in both developed and developing countries, causing approximately 5.8 million deaths worldwide [1]. Research indicates that injury is the leading cause of death, hospitalization, and disability in the first four decades of life [2, 3].

Moreover, research by Briese T. et al. delved into the trends of orthopedic injuries in traffic accident victims, underscoring the profound effect these events have on the victims' health and life quality [4]. Paryavi's studies offer a perspective on the intricacies of injuries to the shoulder area, including the upper limb and shoulder girdle, along with their management [5].

The research authored by Moulaei K. et al., provides an in-depth analysis of telerehabilitation technologies for upper limb disabilities [6]. The study conducted a scoping review by searching databases like Web of Science, PubMed, and Scopus until July 2021. The most widely used services were the evaluation of exercises and musculoskeletal function of patients by therapists, recording of patients' rehabilitation exercises, and prescribing new rehabilitation exercises. The study found that virtual reality technologies, smart wearables, and robots were commonly used in telerehabilitation services. The most important outcomes identified were improvement in musculoskeletal functions, increased patient interest and motivation, and greater adherence to rehabilitation exercises. This comprehensive review underscores the potential of telerehabilitation in providing equitable access to rehabilitation services, improving musculoskeletal function, and empowering individuals with a variety of rehabilitation capabilities.

The study led by Samantha G. Rozevink et al. explores the long-term effects of using an unactuated training device combined with a telerehabilitation platform for upper limb rehabilitation in stroke patients [7]. The study concludes that training effects were still present at six months follow-up, but due to the small sample

size and study design, the results should be interpreted with caution. This research contributes to understanding the potential and limitations of telerehabilitation for long-term recovery in stroke patients.

Chingyi Nam et al. presents a study on the feasibility and effectiveness of a home-based telerehabilitation program for upper limb rehabilitation in stroke patients [8]. This program utilizes an electromyography (EMG)-driven wrist/hand exoneuromusculoskeleton (WH-ENMS) to assist patients in their rehabilitation exercises. The study involved 11 chronic stroke patients who participated in a single-group trial, where their training progress, including frequency and duration, was telemonitored. The study concluded that the home-based self-help telerehabilitation program is feasible and effective for improving the motor function of the upper limb.

While existing scientific research has largely focused on telerehabilitation for stroke patients, the potential benefits of this technology for those recovering from road accidents remain underexplored [9, 10].

AIM

This study aimed to examine the characteristics of upper limb and shoulder injuries combined with chest trauma in road accident victims and evaluate the effectiveness of telemedical monitoring and a newly developed telerehabilitation model in patient recovery. Such insights are crucial for aiding clinical decision-making, formulating treatment strategies and preventive measures, and potentially reducing the incidence of complications and mortality rates.

MATERIALS AND METHODS

Our study incorporated 136 medical records of inpatients who had sustained upper extremity and chest injuries, constituting a retrospective group. Additionally, in the main group, we included 73 patients with similar injuries of the upper extremity and chest. These patients were consecutively enrolled in the study over a 5-year period at the same hospital, from September 2019 to November 2023.

Our analysis focused on patient demographics such as age, gender, specific diagnoses, and the nature of the injuries sustained. We categorized the results based on gender, age groups, and types of road users, and conducted comparative analyses across these groups.

To ensure the confidentiality and protection of the patients' personal data, any identifying information was omitted from the analysis. This data was securely stored in an electronic format, with restricted access to uphold privacy standards.

In our study, the control group, consisting of 136 patients, underwent traditional rehabilitation procedures for a period of three weeks following their injury. This group received the usual care, which encompassed generally accepted methods of rehabilitation therapy. These methods included treatments like massage, myostimulation, and exercises conducted in a pool.

On the other hand, a total of 73 subjects were enrolled in the telerehabilitation group. This group also participated in the study for a three-week period post-injury. However, instead of the conventional rehabilitation methods, they were trained with a specially designed set of exercises using a prototype device intended for home use. This approach aimed to assess the efficacy and practicality of telerehabilitation in comparison to traditional rehabilitation methods.

To evaluate the effectiveness of rehabilitation in both groups, we utilized the QuickDASH (Disabilities of the Arm, Shoulder, and Hand) questionnaire [12], a universally recognized tool for assessing functional limitations of the arm, shoulder, and hand. This method encompasses 11 criteria designed to evaluate physical capabilities and symptoms in patients with either single or combined injuries of the upper limb and shoulder girdle.

Each question in the QuickDASH offers five response options, reflecting the varying degrees of difficulty patients experience while performing specific tasks. These responses range from 1, indicating the ability to perform the task freely, to 5, denoting that the task is impossible to perform. The intermediate options include 2 for minor difficulties, 3 for moderate difficulty, and 4 for tasks that are very difficult to perform. This graded approach allows for a nuanced assessment of the rehabilitation process's effectiveness.

For home remote monitoring, 73 subjects in the test group used a portable device equipped with an Axis-sensor, temperature, volume, and pulse sensors, which were attached to the injured limb (Fig 1.). The device's software enabled the monitoring of several key parameters: biomechanical movement, local temperature, the frequency of active movements, and the volume of the injured limb.

During the execution of prescribed home exercises, data from the subjects' portable devices were continuously recorded. This data was then transmitted to a server via a cellular Internet connection. Additionally, the information was sent to the personal smartphones of the rehabilitation doctors. The data was presented both in digital form and graphically, allowing for real-time monitoring and assessment of the rehabilitation progress. This advanced monitoring method aimed to enhance the effectiveness and customization of the rehabilitation process.

Fig. 1. Portable device equipped with sensors.

The tele-rehabilitation protocol in our study included several key components:

1. Fixation of the Portable Device: Patients were instructed to attach the portable device to their injured limb. This device was integrated with customized software specifically designed for monitoring various health parameters.
2. Home Exercises for Rehabilitation:

- Passive Flexion-Extension in the Elbow Joint: This exercise involved gentle bending and straightening of the elbow, done passively without the patient's muscular effort.
- Active Flexion-Extension in the Elbow Joint: Unlike the passive exercise, this involved the patient actively bending and straightening their elbow, using their own muscle strength.

3. Pain Assessment Training: All patients were trained to assess and report their pain levels using a 10-point scale. This subjective assessment was crucial for monitoring their progress and adjusting rehabilitation exercises accordingly.
4. Software Utilization: The software used in this model served as a personal rehabilitation record. It facilitated the storage of health information and communication between the patient and health professionals.
5. Basic Measures Recorded: For each patient, the software recorded essential health metrics, including blood pressure, limb volume, waist and chest measurements, pulse, weight, height, sex, blood oxygen saturation, local temperature, movement activity, and the condition of connective tissue.

It's important to note that the initial implementation of this telerehabilitation model did not involve the prescription of medications or joint injections. This approach was focused on the use of telemedicine and physical rehabilitation exercises to aid recovery.

In our study, each patient's rehabilitation process was highly personalized. Based on the individual condition of each patient, the rehabilitation doctor crafted a tailored rehabilitation plan for every subject. This plan included a detailed activity schedule, ensuring that the rehabilitation exercises were aligned with the patient's specific needs and capabilities.

Key to this approach were personal goals set for daily movement activity and various steps in the rehabilitation program. These goals were designed to be both achievable and progressive, helping patients to gradually regain their physical capabilities.

The distinction between the telerehabilitation group and the control group in our study was a pivotal factor in assessing the effectiveness and benefits of these two approaches to rehabilitation.

In the telerehabilitation group, each patient was paired with a rehabilitation doctor who offered guidance and support from a distance. This arrangement facilitated continuous monitoring, enabling the rehabilitation plan to be dynamically adjusted according to the patient's individual progress and feedback. The essence of this approach was its personalized nature; the rehabilitation was not a one-size-fits-all regimen but rather a tailored program that evolved in response to the specific needs and conditions of each patient.

Table 1. Functional results comparing the retrospective and main groups

	Retrospective group	Main group	p-value
The average time spent by patients on rehabilitation exercises per day.	29±8 min	42±4 min	p<0,005
The number of patient visits to the medical facility over a period of 3 weeks.	12±2	4±2	p<0,005
The total time dedicated by the rehabilitator to each patient during the 3-week period.	263±15 min	92±14 min	p<0,005
qDISH last day of rehabilitation			
Excellent (0-25 points)	9 (6.62 %)	11 (15.07 %)	
Good (26-50 points)	97 (71.32 %)	52 (71.23 %)	p=0,152
Satisfactory (51-84 points)	24 (17.65 %)	8 (10.96 %)	
Unsatisfactory (85-100 points)	6 (4,41 %)	2 (2,74 %)	

p-values were obtained using the chi-square test for categorical variables and analysis of variance (ANOVA test) for continuous variables.

On the other hand, the control group received traditional rehabilitation at home, but this did not include the dedicated oversight of a personal doctor. They adhered to standard rehabilitation protocols that were not customized to the individual patient's evolving requirements. This meant that while they received the necessary exercises and treatments, these were not modified in real-time based on their specific recovery trajectories or feedback.

This fundamental difference in approach was key to our study. It allowed us to explore the impact of personalized, remote rehabilitation support, particularly in terms of patient outcomes, engagement, and satisfaction, compared to the more generalized approach of traditional home-based rehabilitation. By contrasting these two groups, we aimed to glean insights into the potential advantages of a more personalized and adaptive rehabilitation model, as provided by telerehabilitation, over the conventional methods.

RESULTS

In the study groups, the percentage distribution of men and women was as follows: Comprising 136 patients in retrospective group, there were 98 men (72.1%) and 38 women (27.9%). Among the 73 patients in main group, there were 52 men (71.2%) and 21 women (28.8%). These percentages indicate a higher incidence of injuries among men compared to women in both groups. However, the proportion of men to women was fairly consistent between the retrospective and main groups. In terms of injury patterns, a significant portion of patients, regardless of their gender, were injured while cycling or walking as pedestrians. This observation underscores the need for focused safety measures and awareness campaigns for these particular groups to potentially reduce the risk of road accidents.

Regarding the age distribution of the patients in our study, the most common age group was those of working age, specifically between 25 to 44 years old. This age group constituted more than forty percent of patients in both the retrospective and main groups, indicating a high incidence of injuries among individuals in their prime working years.

Conversely, the smallest age group differed between the two groups. In the retrospective group, the least represented age group was the younger adults aged 18-24. In the main group, the smallest group consisted of individuals aged over 60. This variation in the age distribution highlights different risk profiles and possibly different lifestyles or activities leading to injuries among these age groups. The prevalence of working-age individuals in both groups underscores the significant impact such injuries can have on the workforce and the importance of targeted prevention and rehabilitation strategies for this demographic.

In the main group of our study, the role of the rehabilitator emerged as a central and defining element in the success of the telerehabilitation process. The systematic monitoring of each patient's clinical condition by the rehabilitator was a cornerstone of this approach. This rigorous and continuous monitoring process included the analysis of various key health parameters, such as the range of motion, pain level reduction, and improvement in limb function.

One of the most significant advantages of this approach was the capacity for real-time, remote adjustments to the telerehabilitation protocol. This adaptability ensured that the rehabilitation process remained optimally efficient and effective, tailored to the evolving needs of each patient. Such flexibility is often not feasible in traditional rehabilitation settings, where adjustments may require physical assessments and can be less responsive to immediate changes in a patient's condition.

The outcomes for both the retrospective and primary groups were analyzed using the QuickDASH scale, a tool designed to measure the disability of the arm,

shoulder, and hand. Additionally, we evaluated several other important metrics, including:

- The average time spent by patients on rehabilitation exercises per day.
- The number of patient visits to the medical facility over a period of 3 weeks.
- The total time dedicated by the rehabilitator to each patient during the 3-week period.

These metrics, summarized in Table 1, provided a comprehensive view of the rehabilitation process, including the time commitment from both patients and medical professionals, and the intensity of the rehabilitation activities. This comprehensive evaluation was essential for understanding the effectiveness of the rehabilitation protocols in both groups.

The data presented in Table I offers a comprehensive comparison of the functional results between the retrospective group and the main group, providing valuable insights into the effectiveness of traditional rehabilitation versus telerehabilitation.

Focusing first on the average time spent on rehabilitation exercises per day, we observe a noticeable difference: while the retrospective group dedicated an average of 29±8 minutes daily, the main group invested more time, averaging 42±4 minutes. This significant increase in daily rehabilitation time in the main group ($p<0.005$) suggests that the convenience and accessibility of telerehabilitation may encourage patients to engage more rigorously in their recovery exercises.

Turning our attention to the frequency of medical facility visits over a three-week period, the contrast is striking. The retrospective group reported an average of 12±2 visits, in stark contrast to the main group, which averaged only 4±2 visits. The markedly reduced need for physical visits in the main group ($p<0.005$) highlights one of the key benefits of telerehabilitation: reducing the logistical burden on patients while still providing effective care.

Regarding the total time a rehabilitator dedicated to each patient over the same period, the efficiency of the telerehabilitation model becomes even more evident. The rehabilitators spent considerably less time with each patient in the main group (92±14 minutes) compared to the retrospective group (263±15 minutes), with a significant difference ($p<0.005$). This efficiency could be attributed to the streamlined nature of remote monitoring and guidance.

Finally, the QuickDASH scores on the last day of rehabilitation provide an interesting perspective on patient outcomes. While there was a slightly higher percentage of 'Excellent' outcomes in the main group, the majority of patients in both groups achieved 'Good' functional results. The lack of a significant statistical difference in these outcomes ($p=0.152$) indicates that, despite the reduced in-person contact and lower time commitment from healthcare professionals in the main group, the overall functional recovery was on par with that of the traditional rehabilitation group.

In essence, Table 1 paints a picture of how telerehabilitation can potentially transform patient care, offering an efficient, less burdensome alternative that does not compromise on the quality of patient outcomes. This represents a promising direction in the field of rehabilitation, combining technological innovation with patient-centric care.

DISCUSSION

The findings from our study provide several key insights into the evolving landscape of rehabilitation, particularly when comparing traditional methods with emerging telerehabilitation approaches.

One of the most striking observations is the increased time patients in the telerehabilitation group spent on daily rehabilitation exercises. This suggests that the convenience and accessibility of telerehabilitation may encourage greater patient engagement and adherence to prescribed exercise regimens. The ease of performing exercises in a comfortable, familiar home environment, coupled with the continuous remote support from medical professionals, likely contributes to this increased engagement [4].

The significantly reduced number of visits to medical facilities and the decreased time commitment required from rehabilitators in the telerehabilitation group underscore the efficiency of this model. This aspect is particularly relevant in the context of healthcare resource optimization and reducing the logistical burden on patients, especially those with mobility challenges or residing in remote areas.

The discovery in our study that there was no notable statistical difference in the functional outcomes, as evaluated by QuickDASH scores, between patients undergoing telerehabilitation and those receiving traditional rehabilitation is of significant importance. This equivalence in QuickDASH scores demonstrates that telerehabilitation, despite involving fewer in-person interactions and requiring less time from healthcare professionals, does not diminish the effectiveness of patient recovery. Moreover, this finding points to the broader applicability of telerehabilitation, especially in scenarios where regular clinic visits pose challenges. This could include situations where patients face mobility issues, live in remote areas, or when there are constraints like pandemics that limit physical contact. In such contexts, telerehabilitation not only emerges as

a feasible alternative but also as a potentially preferred method of delivering rehabilitation services [6].

The study also sheds light on the potential of personalizing rehabilitation plans based on real-time monitoring. The ability of medical professionals to remotely adjust rehabilitation protocols in response to patient progress or challenges is a significant advantage, allowing for more dynamic and responsive care. These findings have important implications for healthcare policy and future practice. The integration of telerehabilitation into standard care practices could enhance the efficiency of healthcare delivery, improve patient accessibility to rehabilitation services, and potentially lead to better patient satisfaction due to the convenience and personalization it offers.

While the results are promising, further research is needed to explore the long-term outcomes of telerehabilitation [6], its applicability to different types of injuries or patient populations, and its cost-effectiveness compared to traditional methods. Additionally, understanding the barriers to its adoption and how to overcome them will be crucial for its wider implementation.

Our study indicates that telerehabilitation is not only a feasible alternative to traditional rehabilitation but also an efficient and patient-friendly option that does not compromise on treatment outcomes. Its adoption could be a significant step forward in modernizing rehabilitation services, making them more accessible and tailored to individual patient needs.

As the healthcare landscape continues to evolve, integrating telerehabilitation into standard care could not only enhance the efficiency of healthcare delivery but also improve patient accessibility and satisfaction.

However, this study also opens the door to further research, particularly in exploring the long-term outcomes of telerehabilitation, its cost-effectiveness, and its applicability across diverse patient populations and injury types.

CONCLUSIONS

The findings reveal that telerehabilitation can significantly increase patient engagement in rehabilitation exercises, primarily due to its convenience and accessibility. This mode of rehabilitation not only reduces the need for frequent medical facility visits but also decreases the time commitment required from healthcare professionals, all while delivering functional outcomes comparable to conventional methods.

The ability to tailor rehabilitation plans based on real-time monitoring and adjust them dynamically to the patient's progress or challenges marks a significant advancement towards more personalized and responsive healthcare.

This study points towards a future where rehabilitation services are more adaptable, patient-friendly, and aligned with the growing digitalization of healthcare, promising a more inclusive and accessible healthcare system for all.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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