International Summit on Science Technology and Humanity
ISETH 2024
ISSN: 2615-1588 (online)

A Systematic Literature Review on Global Treatment for Post-Poliomyelitis Syndrome

Aisyah Nabilah[1 a)], Laverda Shauma Ratu[1 b)], Windy Cahya Cantika[1 c)], Ajeng Sayidah Wardani[1 d)], Indriyati Oktaviano Rahayuningrum[2 e)]

[1] Faculty of Medicine, Universitas Muhammadiyah Surakarta, Surakarta, Indonesia
[2] Department of Public Health, Faculty of Medical, Universitas Muhammadiyah Surakarta, Surakarta, Indonesia

Corresponding author : j500210079@student.ums.ac.id

Abstract

Introduction: Polio can lead to Post-Poliomyelitis Syndrome (PPS) due to the long-term effects of poliovirus on motor neurons. After poliomyelitis's initial recovery, patients may experience neuromuscular symptoms 15 years post-infection. Polio survivors often deal with residual muscle atrophy and joint problems, acute flaccid paralysis, postural deformities, and respiratory muscle weakness. There are various rehabilitative treatments to manage PPS, including occupational therapy, exercise, medications, and surgery that shown effectiveness in improving patients' mobility and QoL.
Purpose: This study aims to identify and evaluate the effectiveness of various global treatment strategies for Post-Poliomyelitis Syndrome.
Methods: This study adheres to Cochrane Collaboration's methodological guidelines for literature reviews. Five databases were utilized, guided by PICO (Population, Intervention, Control, Outcome) framework. The inclusion criteria specified original articles published in English between 2020-2024, with full-text availability. Data regarding treatment outcomes were synthesized, leading to the formulation of conclusions.
Results and Discussion: The search obtained 2040 studies, and 1835 abstracts were reviewed. Following full-text assessment, 187 papers were examined, and 19 studies were included. Most of the studies had an RCT design in outpatient setting. Interventions with self-management programs, Hinge-Knee Replacement (HKR), interactive videogame exercises, Radio Electric Asymmetric Conveyer (REAC), Whole-Body Vibration (WBV), Total-Knee Arthroplasty (TKA), and Knee-Ankle-Foot Orthoses (KAFO) showed significant results ($p<0.005$). While L-citrulline supplementation and PVP-lavage intervention showed no significant effect with post-polio syndrome.
Conclusion: This research highlights the significance of tailored healthcare management of PPS according to the patient's severity, offering a variety of approaches that can improve the patient's QoL and independence.
Keywords: *Polio Disease, Post-Poliomyelitis Syndrome, Treatment*

Introduction

Polio or poliomyelitis, also known as childhood paralysis, is caused by poliovirus, primarily affects children under five through fecal-oral transmission and spreads through contaminated objects and food (Ruszel & Iwanicka, 2020). Polio is an extremely infectious illness that primarily affects children who are younger than five years old. The poliovirus leads to paralysis in 1 out of every 200 infections (Siddiqui & Bowditch 2023;Awaidy & Khamis, 2020).

The poliovirus (types 1, 2, and 3) spreads through fecal-oral transmission and predominantly impacts the nervous system. The virus usually gains entry into the body via the oral route, replicating in the oropharynx and gastrointestinal tract before disseminating to the central nervous system (CNS) (Dean & Olsén, 2022). Once it reaches the CNS, the virus can damage motor neurons, resulting in muscle weakness and, in severe cases, paralysis. The underlying mechanism is thought to involve the overuse of enlarged motor units, which results in distal axonal degeneration (Koopman & Nollet, 2024). The neurotropic characteristics of the poliovirus result in anterior horn cell degeneration within the cord spinal, leading to motor function impairment and significantly affecting the patient's mobility (Saraswathy, 2021).

The first epidemics were recorded in the late of 19th century, by the mid-20th century, the disease had established a global presence. The Worldwide Initiative for Polio Eradication Initiative was launched in 1988 and has significantly decreased the incidence of wild poliovirus. In 2020, cases were reported exclusively in Pakistan and Afghanistan (Peel, 2020). Global polio eradication efforts have made significant progress, with wild poliovirus (WPV) cases decreasing by over 99.9% since 1988 (Gunhui et al., 2023;Wilkinson et al., 2022). However, challenges persist, there have been occurrences of circulating vaccine-derived poliovirus (cVDPV) and persistent transmission of wild poliovirus (WPV) in

Afghanistan and Pakistan (Gunhui et al., 2023). Previously Indonesia declared polio-free, experienced outbreaks in 2019 and 2024 due to cVDPV. (WHO, 2024). On January 4, 2024, Indonesia again reported one additional case of polio (type cVDPV2) through AFP surveillance in Kab. Sampang, In East Java, paralysis cases began on December 6, 2023. In addition, on December 22, 2023, 1 case of cVDPV2 was reported in Kab. Pamekasan, East Java with onset on November 22, 2023. So the total number of cVDPV2 type Polio cases in Indonesia in 2022-2023 in 7 cases (one in Central Java, one in West Java, two in East Java, and three in Aceh, alongside a total of 20 cVDPV2 detections in healthy children (nine in East Java, seven in West Java, and four in Aceh) (Kemenkes RI, 2024).

Poliomyelitis and its long-term effects pose significant health risks, particularly as patients age. Age at vaccination may influence subsequent health outcomes, with early polio vaccination potentially associated with an increased risk of CNS demyelination (Ismail & Salama, 2022). In Indonesia, the proportion of infants under 18 months who have received complete polio vaccinations is merely 35.83%. Various factors, including the mother's age, educational background, socioeconomic status, and healthcare accessibility, influence the vaccination rates (Mediarti et al., 2020). Additionally, risk factors contributing to functional decline in individuals with a history of polio include advanced age, ethnicity, and the use of assistive devices during childhood (Meiner et al., 2021).

Research on poliomyelitis and related health issues reveals complex gender dynamics. Gender was not identified as a significant risk factor for functional decline in individuals who have survived polio (Meiner et al., 2021), it plays a crucial role in polio eradication efforts. Female frontline workers are essential for accessing conservative households but face unique challenges including safety risks and limited career advancement (Kalbarczyk et al., 2022). The gender composition of management teams can impact program planning and accountability (Kalbarczyk et al., 2021).

Poliomyelitis remains a significant health concern, particularly in endemic countries like Pakistan (Shabbir et al., 2020). Unvaccinated individuals are at high risk for paralytic disease, as evidenced by a recent case in New York where community transmission was detected through wastewater surveillance (Leggiadro, 2022). Vaccination coverage varies significantly across different residential settings, with rural areas consistently showing lower fully immunized child (FIC) rates compared with urban areas. In Nigeria, FIC rates improved from 2003 to 2013 but remained suboptimal. Factors associated with higher FIC rates include maternal education, antenatal care attendance, and delivery in health facilities. Addressing these factors, particularly improving maternal education, could substantially increase FIC rates across all residential settings (Obanewa & Newell, 2020).

Polio infections are asymptomatic or cause only minor flu-like symptoms, the more severe cases can result in complications such as acute flaccid paralysis, postural deformities, and respiratory muscle weakness. Polio survivors often deal with residual muscle atrophy and joint problems that can persist long after the initial infection has resolved (Zang et al., 2023). The impact on motor functions can vary widely, from partial to total paralysis (Qin et al., 2020).

Polio can lead to post-poliomyelitis syndrome (PPS) due to the long-term effects of the poliovirus on motor neurons. After an initial recovery from poliomyelitis, individuals may experience new neuromuscular symptoms, typically 15 years or more post-infection. This phenomenon occurs in approximately 25% to 60% of polio survivors, characterized by muscle weakness, abnormal fatigability, and generalized fatigue (Khan & Virani, 2022;Punsoni et al., 2023). PPS can severely affect an individual's quality of life by limiting physical capabilities and reducing functional independence (Laffont et al., 2024). Symptoms may include new-onset muscle weakness, generalized fatigue, and heightened pain. Patients with post-polio syndrome face a heightened risk of osteoporotic fractures, with 52.2% experiencing at least one fracture (Sherf et al., 2020). This condition poses additional psychological burdens such as depression and anxiety due to the progressive the disability (Latifoglou et al., 2022).

There are various rehabilitative treatments available for managing PPS. These include physical therapy aimed at strengthening unaffected muscle groups while avoiding overuse of weakened muscles, occupational therapy to aid in adapting to daily activities, and supportive treatment (braces and mobility assistance tools) (Tetz & Schoenbeck, 2023). Additionally, non-fatiguing exercises, pain management through medication, and lifestyle adjustments to minimize exertion are integral parts of a comprehensive PPS treatment plan. Multidisciplinary approaches involving physical therapists, neurologists, and occupational therapists have shown effectiveness in improving patients' mobility and quality of life (Dean & Olsén, 2021).

The main aim of this systematic literature review is to assess evaluate and examine the effectiveness of various international treatment approaches for Post-Poliomyelitis Syndrome. Given that PPS can significantly hinder mobility and daily functioning, this review seeks to analyze current rehabilitative and medical interventions to determine which treatments provide the highest efficacy by synthesizing existing research. This systematic literature review aims to guide healthcare practitioners in developing evidence-based treatment protocols that enhance the mobility and overall well-being of individuals affected by Post-Poliomyelitis Syndrome.

Method

Study Design and Research Question

The systematic literature review was carried out in accordance with the protocols established in the Cochrane Handbook

for Systematic Reviews of Interventions. This involved formulating a research question, establishing criteria for inclusion and exclusion, identifying and selecting relevant studies, and presenting the data. Additionally, the study's methodology incorporated the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020). The investigation's question was, "What is the most effective treatment for Post-Poliomyelitis Syndrome (PPS)?".

Inclusion and Exclusion Criteria

Taking the research question, led to the formulation of inclusion and exclusion criteria were established based on an initial review of the literature and multiple discussions among the authors, following the PICO framework (population, intervention, comparison, and outcome). The study incorporated controlled clinical trials and investigations focused on the treatment of Post-Poliomyelitis Syndrome (PPS). Original articles that were published in English from 2020 until 2024, and accessible full-text, were considered eligible for the study.

Search Strategy

The literature was accessed with Publish or Perish Software 8 on Windows, which utilized the following five electronic databanks: PubMed, Google Scholar, Semantic Scholar, Crossref, and OpenAlex. Literature searched the databases without having to be concerned with specific study designs or language restrictions from 2020 until 2024. The research conducted by the team involved developing a strategy to identify the research subject, guided by the comprehensive study objectives and initial search parameters. Medical Subject Headings (MeSH) were sourced from the National Library of Medicine (NIH) MeSH database. The search terms utilized in the Literature Review included “Post-Poliomyelitis Syndrome” OR “Post Poliomyelitis Syndrome” OR “Post-Polio Syndrome” OR “Post-Polio Syndromes” AND “Treatment” OR “Therapy”. These concepts were integrated using the Boolean operator “AND” to ensure that all relevant concepts were included in the final search results. Upon completion of the literature search across various databases, a total of 2040 articles were identified. The team subsequently eliminated 166 duplicate entries and 39 studies that were not in English.

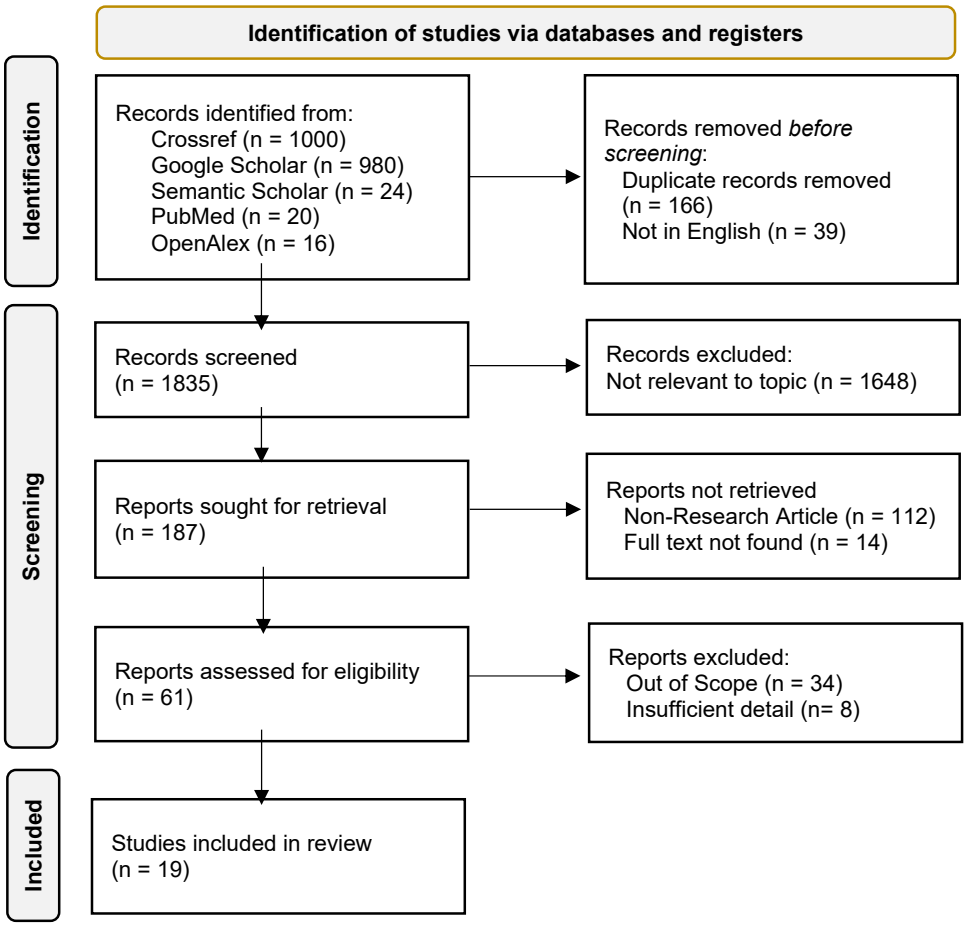

Figure 1. PRISMA Flow Chart Diagram.

Study Selection

The study selection process was divided into two distinct phases: the initial identification of titles and abstracts, followed by a review of the full texts. The detailed search and screening methodology is illustrated in the 2020 PRISMA flowchart, as shown in **Figure 1**. During the first phase, separate researchers assessed the titles and abstracts for potential inclusion, eliminating studies that did not meet the necessary eligibility criteria. In the second phase, the researchers independently evaluated the eligibility of all studies identified in the first phase. Any discrepancies that arose during the selection process were thoroughly examined by the researchers, leading to a consensus. The target population (P) consisted of individuals who are Polio survivors or patients with Post-Poliomyelitis Syndrome. The interventions (I) included both pharmacological and non-pharmacological treatments, while the comparison (C) involved any alternative procedures. The outcome measures (O) demonstrated statistically significant effectiveness of the treatments for Post-Poliomyelitis Syndrome.

Data Synthesis

The findings of the study are presented as the mean difference in post-intervention values when comparing baseline (pre-test) and follow-up (post-test) data for both the intervention and control groups. This includes 95% confidence intervals and p-values derived from the pre-test assessments of both groups. The main emphasis was on evaluating the average change resulting from the treatment in contrast to the control group.

Results and Discussion

Study Selection

Data search using the Publish or Perish (PoP) 8 tool was conducted on November 7, 2024, at 12:30:24 p.m., with five electronic databanks including PubMed, Google Scholar, Semantic Scholar, Crossref, and OpenAlex. The research literature for the efficacy of treatment regimens for PPS patients led to 2040 studies. After the duplicate records and the language were removed, 1835 documents were evaluated on an abstract level. Of the remaining papers, 1648 were removed, which leaves 187 documents for full-text retrieval. Articles that were not researched or had no full text were removed. As many as 61 papers evaluated the full text in terms of inclusion criteria, 19 of these studies were part of the systematic review.

Result

Study Characteristics

The characteristics of the studies included in this systematic literature review are presented in **Table 1**, which outlines the authors and the years of publication, research title, research origin, study design, study setting, and superficial main findings of the study. Six of the 19 studies included studies in the Brazil region, three studies in Italy, the Netherlands and Switzerland had 2 studies, and there was 1 study each from the UK, Argentina, Turkey, Pakistan, Spain, and India. Nine of the 19 studies were Randomized Control Trial (RCT) six of which were single-blind and the rest were double-blind. Eight studies were retrospective cohort studies, and the other two studies had a cross-sectional research design. Eight studies had an in-patient setting, and the rest had an out-patient setting. In the main findings, 17 studies produced statistically significant results on the effectiveness of the intervention, while the other two produced non-significant results.

Table 1. Characteristics of Post-Poliomyelitis Syndrome Treatment Studies

Author	Title	Region	Study Design	Main Findings
Inpatient				
Babu et al., 2022	Strategies in the management of femoral fractures in post-polio limb a retrospective analysis of 10 patients with 3-year follow-up	India	Retrospective analysis	Extramedullary internal fixation devices provide effective stability and functional results for fractures in post-polio limbs without major complications.
Curtis et al., 2020	The value of a post-polio syndrome self-management program	United Kingdom	Retrospective cohort	The self-management program for post-polio syndrome notably alleviated symptoms including fatigue, pain, atrophy, and bulbar function. There was a significant enhancement in participants' understanding of PPS following the program.

Author	Title	Region	Study Design	Main Findings
Digennaro et al., 2022	Total Knee Replacements Using Rotating hinge implants in polio patients: clinical and functional outcomes	Italy	Retrospective analysis	Total knee replacement using rotating hinge implants significantly improves knee stability function and quality of life in polio patients.
Manzetti et al., 2024	Survivorship of Total Knee Arthroplasty in Poliomyelitis Patients: Long-Term Results from the R.I.P.O Registry and Single-Institution Retrospective Study	Italy	Retrospective comparative	TKA in post-polio syndrome patients showed clinical and functional outcomes improved significantly, with increasing KSS scores. TKA is recommended as the first-line treatment for post-polio syndrome patients, replacing knee arthrodesis.
Motta et al., 2024	Efficacy of REAC Neurobiological Optimization Treatments in Post-Polio Syndrome: A Manual Muscle Testing Evaluation	Brazil	Randomized control trial (RCT) single-blind	REAC treatments significantly improved muscle strength in PPS patients. REAC treatments may reorganize motor patterns and reduce functional overload.
Putananickal et al., 2021	Treatment with L -Citrulline in patients with post-polio syndrome: A single-center, randomized, double-blind, placebo-controlled trial	Switzerland	Randomized control trial (RCT), Double-blind	None of the secondary endpoints, including motor function and muscle strength, showed significant changes with L-Citrulline treatment.
Tigani et al., 2024	Long-Term Results of Third Generation of Rotating Hinge Arthroplasty in Patients with Poliomyelitis	Italy	Retrospective analysis	The third generation of rotating hinge knee replacements demonstrated considerable improvements in both clinical and functional scores among polio patients, with no instances of mechanical failure reported.
Tillet et al., 2022	Diluted Povidone-Iodine Lavage in Total Hip and Knee Replacement: A Retrospective Comparative Study	Argentina	Retrospective comparative	The study revealed a higher likelihood of infection occurring within 90 days after surgery for patients who did not receive diluted PVP-I lavage; nonetheless, this variation did not reach statistical significance.
Outpatient				
Brehm et al., 2021	Effect of Carbon-Composite Knee-Ankle-Foot Orthoses on Walking Efficiency and Gait in Former Polio Patients	Netherlands	Retrospective analysis	Carbon-composite KAFOs significantly reduced the energy cost of walking compared to conventional KAFOs. There was an increase in energy expenditure, and patient satisfaction with carbon-composite KAFOs.
Brehm et al., 2021	Self-reported functional ambulation is related to physical mobility status in polio survivors; a cross-sectional observational study.	Netherlands	Cross-sectional	The self-reported categorization of functional ambulation into three distinct levels holds clinical significance for polio survivors, correlating well with both objective and self-reported measures of physical mobility.
Campos et al., 2020	Assessment of a fixed-dose combination of l-carnitine + piracetam in the treatment of pain in post-poliomyelitis syndrome	Brazil	Randomized control trial (RCT), Double-blind	The fixed-dose combination of L-carnitine and Piracetam resulted in marked improvements in functional performance for PPS patients when compared to a placebo. While both groups experienced a decrease in pain intensity, only the active treatment group exhibited significant enhancements.
Gocheva et al., 2020	Health-related quality of life, self-reported impairments, and activities of daily living concerning muscle function in post-polio syndrome	Switzerland	Retrospective analysis	A significant relationship was found between daily living activities and clinical muscle function results, along with their impact on health-related quality of life (HRQOL) and impairments associated with post-polio syndrome (PPS).
Gusi et al., 2022	Health-related quality of life and multidimensional fitness profile in polio survivors	Spain	Cross-sectional	Physical activity programs focusing on mobility and physical functioning are recommended to reduce fall risk and fatigue also improving the physical fitness and HRQoL of polio survivors.
Irshad et al., 2023	Effects of Customized Biomechanical Footwear on Gait and Balance in Individuals with Polio: A Randomized Controlled Trial	Pakistan	Randomized control trial (RCT) single-blind	Customized biomechanical footwear has demonstrated a substantial improvement in gait parameters such as step length, stride length, step width, cadence, and speed among individuals affected by polio. Additionally, this intervention has led to significant enhancements in balance.
Motta et al., 2020	L-carnitine+piracetam for fatigue and muscular strength of patients with post-poliomyelitis	Brazil	Randomized control trial (RCT) double-blind	The fixed-dose combination of L-carnitine and Piracetam effectively reduced fatigue and improved muscle strength in some muscle groups in PPS patients. The treatment was safe and well-tolerated, with no significant adverse effects.
Motta et al., 2023	Improving Strength and Fatigue Resistance in Post-Polio Syndrome Individuals with REAC Neurobiological Treatments	Brazil	Randomized control trial (RCT) single-blind	REAC neurobiological modulation treatments significantly improved muscle strength, physical endurance, and a significant reduction in overall fatigue levels as measured by the RPFS.
Nogueira et al., 2024	Neurobiological modulation with REAC technology: enhancing pain, depression, anxiety, stress, and quality of life in post-polio syndrome subjects	Brazil	Randomized control trial (RCT) single-blind	REAC treatments resulted in notable decreases in pain, depression, anxiety, and stress levels in patients with post-polio syndrome, indicating that REAC could be a safe and effective alternative to traditional therapies for this condition.

Author	Title	Region	Study Design	Main Findings
Silva et al., 2020	Effects of the Interactive Videogame Nintendo Wii Sports on Upper Limb Motor Function of Individuals with Post-polio Syndrome: Randomized Clinical Trial	Brazil	Randomized control trial (RCT), single-blind	Both interactive video games and active exercises contributed positively to motor function, overall functionality, balance, pain reduction, and fatigue alleviation in individuals with post-polio syndrome. Notably, interactive video games yielded greater enhancements in dexterity compared to active exercises.
Topaloğlu et al., 2022	The effect of adding whole-body vibration exercises to a home exercise program on muscle strength in patients with post-polio syndrome	Turkey	Randomized control trial (RCT) single-blind	Both WBV and control groups showed increased knee muscle strength, but WBV was not superior. WBV exercises reduced the impact of fatigue on psychosocial and cognitive aspects.

PICO Analysis of the Study

The PICO analysis consisting of the Population, Intervention, Comparison, and Outcome of the journals included in this systematic literature review are presented in **Table 2.** The study population was dominated by female participants aged 18 years and above. Three studies reported pharmacological interventions of fixed-dose L-Citrulline combined with Piracetam and Povidone-Iodine lavage (PVP-l). Other studies reported non-pharmacological interventions with self-management programs, Hinge Knee Replacement (HKR), interactive videogame exercises, Radio Electric Asymmetric Conveyer (REAC), Whole-Body Vibration (WBV), Total Knee Arthroplasty (TKA), and Knee-Ankle-Foot Orthoses (KAFO). The comparator in ten studies was a follow-up after the intervention between 1-6 months, while the other nine studies utilized a control group for comparison.

The self-management program designed for individuals with post-polio syndrome demonstrated a significant statistical reduction in fatigue ($p= 0.005$). The Rotating Hinge Total Knee Arthroplasty (RHK) intervention also yielded a significant statistical enhancement, ($p= 0.003$). Furthermore, the impact of interactive video game training on dexterity was notably significant in the group of IVG intervention, with a p-value of 0.0001. In patients with post-polio syndrome, REAC treatment showed a statistically significant improvement in quality of life, with a p-value of 0.02. Additionally, a fixed-dose of L-carnitine combined with Piracetam resulted in a significant statistical decrease in pain intensity across both active treatment groups, with a p-value of 0.009. Whole Body Vibration (WBV) exercise was found to enhance the effects of fatigue on psychosocial and cognitive aspects, statistical significance ($p<0.05$).

The survival rate for total knee arthroplasty (TKA) after ten years was reported at 86.6%. Additionally, the use of carbon composite KAFO resulted in a significant 8% reduction in the energy expenditure required for walking ($p<0.001$). There were notable differences in the correlation between functional ambulation rates and indicators of physical mobility ($p < 0.001$). Customized biomechanical footwear significantly enhanced both gait and balance, with a p-value of less than 0.005. Variations in physical fitness outcomes, including aerobic endurance, mobility, and hand strength, were statistically significant, with a p-value <0.01. The impact of total knee replacement utilizing the RHK implant led to a significant enhancement in both clinical and functional Knee Society Scores, with a p-value of <0.005. A significant correlation was identified between daily living activities and clinical outcomes related to muscle function ($p < 0.01$). In contrast, daily supplementation of 15 g of L-citrulline was administered over 24 24-week periods, as well as the PVP lavage intervention did not yield statistically significant effects on either primary or secondary endpoints related to Post-Poliomyelitis Syndrome.

Table 2. PICO Analysis of Post-Poliomyelitis Syndrome Treatment Studies

Author	Population	Intervention	Comparison	Outcome
Inpatient				
Babu et al., 2022	•Participation Count: 10 participants •Mean age: 34 ± 12 years 8 males and 2 females	Locking compression plate, dynamic hip screw, cancellous screw fixation, total hip replacement	Measurement after fixation and replacement treatments.	The average follow-up duration was 37.8 ± 16.4 months. None of the participants experienced secondary implant failure or any other complications.
Curtis et al., 2020	• Participation Count: 214 •Median age of 61.3 years old •63% female •Most common residual effects from polio were in the lower limbs	A residential self-management program that encompasses physical exercise, fatigue management, pacing strategies, education on early fatigue indicators, and consistent sub-maximal exercise, coordinated by a multidisciplinary team.	Measurements on follow-up 6 months later.	The self-management program designed for individuals with post-polio syndrome resulted in statistically significant enhancements in various areas, including fatigue (P=0.005), pain (P=0.001), muscle atrophy (P=0.002), bulbar symptoms (P=0.003), walking speed (P=0.003), walking distance (P=0.029), and understanding of the condition (P=0.001).

Author	Population	Intervention	Comparison	Outcome
Digennaro et al., 2022	•Participation Count: 14 participants •Age range: 41 to 84 •Average age: 63.9	Total knee replacement using rotating hinge knee prostheses (RHK), with collateral ligament release and cemented implants for stability.	Measurement after RHK surgery treatments.	The treatment effect of total knee replacement using RHK implants resulted in significant improvements in both clinical and functional Knee Society Scores, with p-values < 0.005.
Manzetti et al., 2024	•Participation Count: 71 (69% females and 31% males) •Age range: 47-83 years old •Mean age: 62.9 for females and 62.5 for males.	Total knee arthroplasty (TKA) serves as a surgical solution for individuals suffering from knee conditions resulting from poliomyelitis.	Measurement after TKA surgical	The treatment involving total knee arthroplasty (TKA) demonstrated a 10-year survival rate of 86.6%. There was no statistically significant effect observed regarding gender, age, or the level of constraint on implant survival (p= 0.062).
Motta et al., 2024	• Participation Count: 17 participants • Age range: 18 to 65 • Mean age: 54.9 ± 4.5 years •70.6% female	NPO, NPPO, and NPPO-CB employ REAC technology.	Assessment of muscle strength and functionality after REAC interventions.	The REAC treatments demonstrated statistically significant enhancements in muscle strength. The focus is particularly on the proximal muscles of the left lower limb and the distal muscles of both lower limbs, with $p < 0.05$ indicating moderate to large effects.
Putananickal et al., 2021	•Participation Count: 29 participants •Mean age: PPS patient aged 70 ± 10 years, and healthy control aged 68 ± 5 years. • 45.5% female of PPS and 43.8% female of control	Administration of 15 g L-Citrulline daily, divided into three doses of 5 g each, for 24 weeks.	Placebo	The treatment with L-Citrulline did not show a statistically significant effect on primary or secondary endpoints related to post-polio syndrome, except for a significant increase in non-essential amino acids (NAA) (estimate = 485.16, 95% CI [128.29, 842.02], p = 0.010).
Tigani et al., 2024	•Participation Count: 11 •9 female and 2 male participants. •Median age of 57.1 at surgery time and 70.2 at final follow-up.	Third-generation rotating hinge total knee arthroplasty (RHK) utilizing RHK NexGen Zimmer implants, performed through a standard medial parapatellar approach while preserving the collateral ligament.	Postoperative clinical and functional outcomes	The treatment showed a statistically significant enhancement in both clinical and functional scores, with p-values recorded at 0.003 and 0.02, respectively.
Tillet et al., 2022	•Participation Count: 1.351 •Median age: 68.53 ± 9.44 •58.55% female and 41.45% male •Underwent either total knee (47.60%) or total hip (52.40%) arthroplasty	Diluted povidone-iodine (PVP-I) lavage during replacement surgeries of a 0.38% PVP-I solution to the surgical site 3 minutes before wound closure. Antibiotic prophylaxis 1g of cefazolin.	Control group without PVP lavage procedure	The likelihood of infection was heightened in the first 90 days post-surgery (OR = 4.5; 95% CI 0.56-36.19) without the intervention. Nevertheless, there were no statistically significant differences observed between the two groups (0.92% vs. 0.21%; p = 0.11).
Outpatient				
Brehm et al., 2021	•Participation Count: 20 participants •Age range: 18 to 70 years old •Mean age: 55 years [SD 9.2]. •KAFO leather/metal/plastic users at least 2 years	Custom-made carbon-composite knee-ankle-foot orthoses (KAFOs) include postural correction, reduction of dorsiflexion stops in the ankle joint, and ischial weight-bearing for some participants.	Conventional LM or PM KAFOs.	The treatment with carbon-composite KAFOs significantly reduced the energy cost of walking by 8% ($p < 0.001$) and reduced increments above norm values by 18%. Patient satisfaction increased by 48% ($p < 0.000$).
Brehm et al., 2021	•Participation Count: 140 (74 males and 66 females) •Age range: 18 and older •Mean age: 59.4 ± 12.1 years	Assessment tools include the 6-minute walk test, the Survey of Physical Functioning Scale (SF36-PF), the Fatigue Severity Scale (FSS), and manual muscle testing of 16 leg muscle groups.	Self-reported program on a week follow-up.	The correlation between functional ambulation levels and physical mobility indicators shows significant differences, with a p-value of less than 0.001 and effect sizes (h^2) between 0.18 and 0.42. The SF36-PF score and walking distance account for 46% of the variance in ambulation levels.
Campos et al., 2020	•Participation Count: 94 (63 active groups and 31 placebo groups) •Mean age of 48.8 ± 6.4 years in active group and 48.5 ± 7.0 years in placebo group. •Predominantly female participants	Oral intake of a fixed-dose combination of L-carnitine (300 grams) and Piracetam (270 grams), administered as two pills three times daily.	Placebo	The treatment of L-carnitine combined with Piracetam resulted in a statistically significant reduction in pain intensity for both the active group (p=0.009) and the placebo group (p=0.03). However, there was no statistically significant difference observed between the two groups (p-value = 0.52).
Gocheva et al., 2020	•Participation Count: 27 participants •Age range: 18 to older •Mean age: 65.5 ± 4.8 •56% males and 44% females	Self-reported impairments associated with post-polio syndrome (PPS) were assessed using the SIPP-RS questionnaire. The evaluation of activities of daily living was conducted	Measurement of muscle strength and function after impairments	A notable correlation was found between daily living activities and clinical muscle function results, particularly assessed through the 6-Minute Walk Distance (6MWD) with $p < 0.01$, and the Motor

Author	Population	Intervention	Comparison	Outcome
		through the IBM-FRS questionnaire. Objective muscle function determined by 6-minute walking distance (6MWD) test and motor function measure (MFM).	activities of daily living treatments.	Function Measure (MFM) with $p < 0.01$. In contrast, self-reported disabilities and health-related quality of life (HRQOL) aspects did not show a correlation with the clinical muscle outcomes, yielding a p-value of 0.33.
Gusi et al., 2022	•Participation Count: 77 (37 polio survivors and 40 healthy control) •Age range: under 60 years. •Participant had no disorders known that would prevent from fitness test.	Physical activity programs emphasize mobility and physical functioning, incorporating specific activities such as walking, self-care, and stair climbing.	Healthy control participant	Differences in physical fitness outcomes such as aerobic endurance, mobility, and hand strength are statistically significant with p-values <0.01.
Irshad et al., 2023	•Participation Count: 30 (15 experimental group and 15 control group) •56.6% males and 43.33% females •Mean age: 48.23 ± 2.4 years	Customized biomechanical footwear incorporates elements like medial arch support, a metatarsal pad, rear foot control, a fiberglass lateral counter, and a rocker sole, all enhanced by physical therapy.	The control group received only in-depth shoes with no modification	The treatment with customized biomechanical footwear significantly improved gait and balance, with statistical significance indicated by p-values less than 0.005.
Motta et al., 2020	•Participation Count: 118 (79 active group and 39 placebo group) •Age range: 22 to 60 years old •Mean age: 48.7 years •Predominantly female	A fixed-dose combination of L-carnitine (330 mg) and Piracetam (270 mg) in tablet form, taken orally as three capsules twice daily.	Placebo	The fixed-dose combination of Piracetam and L-carnitine was effective in reducing fatigue and improving muscle strength, with statistically significant improvements in fatigue scores (e.g., FSS: V1-V2 $p = 0.001$).
Motta et al., 2023	•Participation Count: 17 participants •11 females and 5 males •Age range: 18 to 65 years •Mean age: 52.6 for males and 56.7 for females	NPO, NPPO, and NPPO-CB employ REAC technology.	Assessment of muscle strength and functionality after REAC interventions.	The REAC neurobiological treatments showed statistically significant improvements in mobility (TUG test: $p < 0.01$, $\eta2 = 0.51$), handgrip strength ($p < 0.01$, $\eta2 = 0.34$), and fatigue reduction (RPFS).
Nogueira et al., 2024	•Participation Count: 17 •Age range: between 18 and 65 years. •Mean age of 25.3 ± 3.1 years. •82% male.	NPO, NPPO, and NPPO-CB with REAC technology.	Measurement after REAC treatments.	REAC treatments in patients with PPS demonstrated statistical significance, showing a reduction in depression ($p = 0.01$). Additionally, there were improvements in QoL ($p = 0.02$), with no reported side effects.
Silva et al., 2020	•Participation Count: 39 •21 women and 18 men •Mean age of 54.57 years (SD = 9.25) •Mean time since PPS diagnosis of 4.89 years (SD = 3.78) •74% right-handed, 26% left-handed	Interactive video gaming using Nintendo Wii Sports (tennis, golf, boxing, and bowling) and active upper limb exercises mimicking these sports movements.	Training based on similar motor demands (AEG)	The treatment effect of interactive videogames on post-polio syndrome was significant for dexterity, with the IVG group ($p=0.0001$) showing better performance than the AEG group ($p=0.001$). Both groups showed comparable enhancements in motor function, overall functionality, balance, pain levels, and fatigue.
Topaloğlu et al., 2022	•Participation Count: 14 (7 males and 7 females) •Age range: 34 to 57 years •Mean age: 45.1 ± 6.6 years. •All diagnosed with PPS	Whole-body vibration (WBV) exercises conducted with a Power Plate device at a frequency of 30 Hz and an amplitude of 2 mm, executed biweekly for six weeks, in conjunction with a home exercise regimen.	The control group only exercised the program without WBV exercise.	The treatment was effective in increasing muscle strength in both groups with statistical significance ($p<0.05$). WBV exercises improved fatigue impact on psychosocial and cognitive dimensions with statistical significance ($p<0.05$). No significant indicate muscle damage on laboratory test ($p>0.05$).

Study Limitations and Effective Therapy Outcome

The limitations and evaluation of effective treatment are presented in **Table 3** below. The limitation in most studies is that the sample size is small, allowing for bias. The limited population of individuals affected by Post-Poliomyelitis Syndrome, coupled with insufficient access to polio-related healthcare, contributes to this situation. Further investigation and validation are required for the interventions involving REAC, Whole-Body Vibration (WBV), and the fixed-dose combination of L-Citrulline with Piracetam, as these represent innovative pharmacological and non-pharmacological strategies.

There are several effective treatment options for Post-Poliomyelitis Syndrome (PPS) including self-management exercise daily living activities program, Whole-Body Vibration (WBV) exercises, Knee-Ankle-Foot Orthoses

(KAFOs), Rotating Hinge Knee (RHK) arthroplasty, Total Knee Arthroplasty (TKA), REAC neuromodulator treatment, including NPO, NPPO, NPPO-CB, and NPO. However, Povidone-Iodine Diluted Lavage (PVP-I) and 15 g L-citrulline supplementation daily for 24 weeks, did not show significant effectiveness.

Table 3. Limitation and Effectivity of Post-Poliomyelitis Syndrome Treatment Studies

Author	Limitation	Effective Treatment Conclusion
Inpatient		
Babu et al., 2022	•Small sample size •Non-homogeneous implants used •Absence of a control group	Extramedullary internal fixation devices (locking compression plates, screws, hemiarthroplasty)
Curtis et al., 2020	•Data was collected for clinical purposes and not as systematic •Only complete data sets were included, which may have bias. •Lack of a control group	Self-management program for individuals with PPS
Digennaro et al., 2022	•Small sample size •Some patients had polio affecting multiple joints, limiting the generalizability of the findings	Total knee arthroplasty (TKA) utilizing rotating hinge prostheses.
Manzetti et al., 2024	•Limited patient-reported outcome data collected •Lack of information on preoperative knee status •Potential confounding factors due to the retrospective study •Variability in surgeons and hospitals performing the procedures	Total knee arthroplasty (TKA) for patients with acute anterior poliomyelitis (APP).
Motta et al., 2024	•Small sample size •Lack of significant improvements in some muscle groups •REAC treatments are a novel approach, and further research may be needed to fully evaluate their effectiveness	REAC neuromodulatory treatments, including NPO, NPPO, NPPO-CB, and NMO protocols
Putananickal et al., 2021	•Handheld dynamometers (HHD) were not ideal for assessing muscle strength. •Self-reported questionnaires did not assess fatigue •The qMRI method used was not appropriate for detecting muscle degeneration.	Daily 15 g of L-citrulline supplementation for 24 weeks, **was not significant.**
Tigani et al., 2024	•Small sample size makes the analysis less reliable •Loss of a patient to follow-up prevented evaluation of a major postoperative complication	The third-generation rotating hinge knee (RHK) arthroplasty.
Tillet et al., 2022	•Authors acknowledge that further research is needed to confirm the benefits of routine PVP-I lavage.	Diluted povidone-iodine (PVP-I) for surgeries, **was not significant.**
Outpatient		
Brehm et al., 2021	•Difficulty determining improvement in energy efficiency specifically versus other factors like weight and rigidity •Small sample size limited the ability to isolate different factors	Carbon-composite knee-ankle-foot orthoses (KAFOs)
Brehm et al., 2021	•The functional classification for ambulation employed in this study has not been previously validated for individuals who have survived polio. •The sample consisted solely of polio survivors who were referred to a rehabilitation clinic due to walking difficulties, which limits the generalizability of the findings.	Physical activities and mobility.
Campos et al., 2020	•Subjective and personal nature of pain •The placebo group did not show the same clinical improvements as the active group	A fixed-dose combination of L-carnitine and Piracetam
Gocheva et al., 2020	•Small sample size •Inclusion criteria focused on higher-functioning participants, limiting generalizability •Short 6-month observation period.	Impairment of daily living activities.
Gusi et al., 2022	•The sampling approach employed was not based on the entire population. •Limited sample size and the application of non-parametric tests could have restricted the potential to identify correlations.	Physical exercise programs focus on mobility and functioning.
Irshad et al., 2023	•Small sample size •The intervention was of brief duration, lasting only 12 weeks •There was an absence of long-term follow-up assessments at 6 months or 1 year to evaluate any lasting effects.	Customized biomechanical footwear and physical therapy.
Motta et al., 2020	•Relatively high dropout rate, which could introduce bias •Potential impact of non-adherence on results •Exploring a novel pharmacological approach, may need further validation	Fixed dose combination of L-carnitine and Piracetam
Motta et al., 2023	•Small sample size •Heterogeneity of the sample •	REAC neuromodulatory treatments, including NPO, NPPO, NPPO-CB, and NMO protocols

Author	Limitation	Effective Treatment Conclusion
Nogueira et al., 2024	•Small sample size makes the analysis less reliable •Lack of control group	REAC neuromodulatory treatments, including NPO, NPPO, and NPPO-CB
Silva et al., 2020	• Small sample size makes the analysis less reliable •Participants could not be blinded to the nature of the intervention. •The assessment of participants' current physical activity levels relied on subjective measures without objective confirmation.	Interactive video game-based training (IVG) and the active exercise group (AEG).
Topaloğlu et al., 2022	•Small sample size •Relatively short follow-up period •Practical difficulties in getting patients to attend the hospital	Home exercise program combined with whole-body vibration (WBV) exercises.

Discussion

Post-Poliomyelitis Syndrome (PPS)

Post-polio syndrome (PPS) is a neurological condition that impacts 20-40% of individuals who have survived polio. It is marked by the emergence or exacerbation of muscle weakness, fatigue, pain, and various other symptoms that can occur many years after the original infection (Ayub et al., 2022). Diagnosis relies on particular criteria, which encompass a history of polio infection a stable duration of no less than 15 years, and gradual onset of new symptoms persisting for at least one year (Khan & Virani, 2022). PPS can mimic motor neuron diseases like ALS, necessitating careful differential diagnosis (Punsoni et al., 2023). Management approaches include self-management programs, which have shown improvements in fatigue, walking speed, and distance. However, these programs may not significantly impact QoL and depression scores (Curtis et al., 2020).

While there is no cure, management focuses on symptom relief and improving quality of life. Interdisciplinary rehabilitation programs can help patients adapt and develop new skills (Ekstrand et al., 2020). Treatment alternatives consist of aerobic physical activity and pharmacological agents, including tricyclic antidepressants and dopamine agonists, and pain management through conservative approaches and minimally invasive techniques (Samaan & Escalon, 2021). Some studies also suggest intravenous immunoglobulin (IVIG) may affect pain reduction and potentially muscle strength improvement in PPS patients (Kariyawasam et al., 2021). Nevertheless, additional high-quality research is required to validate these advantages. Alternative treatment options may encompass aerobic exercise as well as pharmacological interventions like tricyclic antidepressants and dopamine agonists (Khan & Virani, 2022). An anthroposophic multimodal treatment has also been investigated for chronic pain management in PPS (Ghelman et al., 2020). Diagnosis of PPS remains challenging and can be affected by social determinants like economic stability and healthcare access (Khan & Virani, 2022).

Comparison between Inpatient and Outpatient Setting

The comparison between inpatient and outpatient care based on the findings in Tables 1, 2, and 3 reveals distinct characteristics and outcomes. Inpatient interventions, such as total knee arthroplasty (TKA) and REAC treatments, demonstrated significant improvements in functional and clinical outcomes, including enhanced muscle strength and better Knee Society Scores, with statistical significance often reported (e.g., $p < 0.005$). However, certain pharmacological approaches, such as L-citrulline supplementation and PVP-lavage, failed to show significant effects. Despite their effectiveness, many inpatient studies faced challenges such as small sample sizes, non-homogeneous participant groups, and the absence of control groups, which introduced potential bias. Furthermore, these studies often lacked data on long-term outcomes and patient-reported quality of life, limiting their broader applicability. Examples of successful inpatient interventions include REAC treatments, which significantly improved neuromuscular coordination, and TKA, which showed an 86.6% survival rate over 10 years despite challenges in preoperative assessments and variable surgical outcomes.

In contrast, outpatient care primarily focused on non-invasive and lifestyle-based strategies, yielding promising results in mobility, strength, and fatigue resistance. Interventions such as interactive video gaming, whole-body vibration (WBV), and customized orthoses like KAFOs demonstrated significant effectiveness in improving patient mobility and satisfaction, with outcomes such as reduced energy costs during walking ($p < 0.001$) and superior dexterity improvements through interactive gaming ($p = 0.0001$). Pharmacological combinations like L-carnitine and Piracetam also showed potential in alleviating fatigue and enhancing muscle strength, although placebo effects varied. Outpatient studies, however, often faced limitations like short durations (e.g., six weeks for WBV) and a lack of long-term follow-up, with subjective measures such as pain scores introducing variability.

In comparing the two settings, inpatient care focuses on high-intensity interventions addressing structural or functional impairments, whereas outpatient care emphasizes non-invasive approaches that improve daily living and quality of life. Both settings are constrained by small sample sizes and limited generalizability due to narrow inclusion criteria and regional specificity. While inpatient treatments prioritize acute corrections, outpatient care is better suited

for managing long-term mobility, pain, and functional independence. These findings highlight the complementary nature of inpatient and outpatient strategies and the importance of tailoring interventions to patient needs.

Physical Exercise

Physical exercise shows promise in treating post-polio syndrome (PPS) and improving the quality of life for polio survivors. Studies indicate that PPS patients have lower health-related quality of life and reduced physical fitness compared with healthy individuals, with mobility-related variables 20-40% lower (Gusi et al., 2022). Adapted physical activity in balneotherapy may help reduce pain and improve cardiorespiratory function in PPS patients, though more research is needed to confirm its effectiveness in reducing fracture risk from falls (Taine & Cadet, 2022;Costa, 2022). Engaging in exercise has demonstrated positive effects on symptoms associated with post-traumatic stress disorder and related issues, including depression, sleep disturbances, substance use, and overall quality of life, although it is not exclusively linked to post-traumatic stress disorder (Björkman & Ekblom, 2022). These findings suggest that tailored physical exercise programs focusing on improving mobility and physical functioning could benefit PPS patients, potentially reducing fall risk and fatigue while enhancing overall quality of life (Gusi et al., 2022).

Total Knee Arthroplasty (TKA) or Total Knee Replacement (TKR)

Total knee arthroplasty (TKA) and total hip arthroplasty (THA) present unique challenges for patients with post-polio syndrome (PPS), yet they can significantly improve quality of life. In patients with PPS, TKA frequently necessitates the use of constrained implants, and rotating hinge designs have demonstrated encouraging outcomes (Digennaro et al., 2022). However, these procedures are associated with higher rates of complications, including periprosthetic fractures, instability, and arthrofibrosis. (Karczewski et al., 2023). For THA, both cemented and uncemented implants have been used, with uncemented designs potentially offering better outcomes. (Upadhyaya et al., 2021). PPS patients undergoing THA face increased risks of postoperative complications such as urinary tract infections and prosthetic dislocation, as well as higher rates of revision surgery within five years compared to non-PPS patients (Mercier et al., 2022). Despite these challenges, arthroplasty remains an effective intervention for improving function and reducing pain in PPS patients with hip or knee arthritis.

Fixed-dose L-citrulline Combined with Piracetam

Recent studies have explored the potential of L-citrulline and related compounds in treating post-polio syndrome (PPS) and other conditions. While L-citrulline alone did not show significant benefits for PPS patients in a 24-week trial (Putananickal et al., 2021). L-carnitine fixed-dose piracetam combine has shown effectiveness in alleviating pain and enhancing functional performance in patients with post-polio syndrome (Campos et al., 2020). In various studies, the combination of L-citrulline and tetrahydrobiopterin therapy demonstrated a more significant enhancement of nitric oxide signaling and a reduction in pulmonary hypertension in neonatal pigs compared to the effects of each treatment separately (Dikalova et al., 2020). L-citrulline supplementation, in conjunction with slow-velocity low-intensity resistance training, has been demonstrated to improve leg endothelial function, boost lean mass, and enhance strength in postmenopausal women suffering from hypertension (Kang et al., 2022). These findings suggest that while L-citrulline alone may have limited effects, its combination with other compounds or interventions could offer promising therapeutic potential for various conditions.

Whole Body Vibration (WBV)

Recent studies have explored novel treatments for post-polio syndrome (PPS) and related conditions. Whole-body vibration (WBV) exercises combined with home exercise programs showed the potential to improve muscle strength in PPS patients, particularly for isometric knee extension on the affected side (Topaloglu et al., 2024). However, WBV did not demonstrate superiority in overall treatment outcomes. PPS patients often exhibit muscle adaptive changes, including a higher percentage of type I fibers and large cross-sectional muscle fiber areas (Larsson et al., 2019). Whole-body cryostimulation (WBC) has emerged as a promising adjuvant therapy for various rehabilitation conditions, potentially benefiting the autonomic nervous system, reducing inflammation, and improving body composition (Capodaglio et al., 2022). Research is currently underway to explore the impact of whole-body photobiomodulation (PBM) therapy on pain, functional abilities, and psychological aspects in individuals suffering from fibromyalgia, with ongoing clinical trials assessing its short- and long-term efficacy (Ledesma et al., 2023).

Knee-Ankle-Foot Orthoses (KAFO)

Recent research indicates that sophisticated knee-ankle-foot orthoses (KAFOs) can greatly enhance mobility and overall quality of life for those with lower-extremity disabilities, including those with post-polio syndrome. Microprocessor-controlled KAFOs (MP-SSCOs) and stance control KAFOs (SCKAFOs) have demonstrated superior outcomes to conventional locked KAFOs. These advanced orthoses improve spatiotemporal gait parameters, reduce energy expenditure, and enhance functional balance (Dluhy et al., 2021;Davis et al., 2014). A bionic KAFO retrofit demonstrated normalization of walking gait characteristics by as much as 99.84% in patients with post-polio syndrome (Payra & Mahadevan, 2021). MP-SSCOs have been associated with a substantial decrease in fall frequency compared to conventional KAFOs and SCOs (Brüggenjürgen et al., 2022). These cutting-edge orthotic technologies enhance quality of life, optimize gait patterns, increase perceived reliability, address key patient burdens such as restricted mobility and emotional strain (Brüggenjürgen et al., 2022;Dluhy et al., 2021).

Radio Electric Asymmetric Conveyer (REAC)

Radio Electric Asymmetric Conveyer (REAC) technology has shown promise as a non-invasive treatment for various conditions. In cases of post-polio syndrome, treatments involving neurobiological modulation by REAC have been shown to enhance strength, physical endurance, and fatigue resistance (Motta et al., 2023). REAC has also been explored as an adjuvant therapy for mental disorders, including depression, anxiety, and bipolar disorder, enhancing cell polarity and improving natural bioelectric activity. (Ahadini et al., 2022). The technology's neuromodulation effects and safety profile make it a potential alternative for drug-resistant mental disorders (Ahadini et al., 2022). Additionally, REAC has shown promising results in wound healing, specifically for pressure ulcers and burn injuries. The Reparative Tissue Optimization (TO-RPR) treatment demonstrated rapid qualitative and quantitative recovery, with effects persisting even after the treatment cycle ended (Fontani et al., 2022). These findings suggest that REAC technology may offer new therapeutic possibilities across various medical fields.

Conclusions

In conclusion, this systematic review highlights several promising Post-Poliomyelitis Syndrome (PPS) treatments. Inpatient care provides effective high-intensity interventions for structural and functional impairments, while outpatient care focuses on non-invasive approaches that enhance mobility, pain management, and quality of life. Both settings face limitations like small sample sizes and short follow-up durations, underscoring the need for tailored, complementary strategies in managing PPS. TKA/TKR surgery significantly aids joint pain and mobility in patients with severe joint degeneration, though careful preoperative assessment is essential. The combination of L-citrulline and piracetam shows the potential to reduce fatigue and improve muscular endurance, though larger studies are needed for confirmation. Tailored physical exercise, including aerobic and resistance training, improves muscle strength and mobility, while Whole-Body Vibration (WBV) serves as a useful alternative for patients unable to perform traditional exercise, supporting circulation and muscle function. KAFO devices offer valuable stability and support for lower-limb weakness, reducing the risk of further musculoskeletal issues. The REAC device provides a novel approach to potentially improve neuromuscular coordination, though more research is needed. Overall, these treatments underscore the importance of personalized care in PPS management, offering diverse approaches that can enhance patients' quality of life and independence.

Acknowledgment

We would like to thank all the research team. Moreover, thank you to the Muhammadiyah Surakarta University for permitting and providing supporting facilities for this research.

References

Ahadini, P. A., Utama, M. B. W., Reihan, A. I., & I'tishom, R. (2022). Review: Radio Electric Asymmetric Conveyer (REAC) as adjuvant therapy for mental disorder. *World Journal of Advanced Research and Reviews*, *13*(1), 280–284. https://doi.org/10.30574/wjarr.2022.13.1.0030

Awaidy, S. T. Al, & Khamis, F. (2020). Wild Poliovirus Type 1 in Oman: A re-emerging threat that requires urgent, targeted, and strategic preparedness. *Sultan Qaboos University Medical Journal [SQUMJ]*, *20*(1), 1. https://doi.org/10.18295/squmj.2020.20.01.001

Ayub, K. A. Mafla., Guzmán-Molano, L. F., Centanaro-Meza, G. A., & Mejia-Mójica, J. A. (2022). The legacy of polio: 2 cases of post-polio syndrome and review. *Revista Mexicana de Neurociencia*, *23*(3). https://doi.org/10.24875/RMN.20000147

Babu, S. A., Dhanasekaran, R., & Muthu, S. (2022). Strategies in the management of femoral fractures in post-polio limb a retrospective analysis of 10 patients with 3-year follow-up. *International Journal of Orthopaedics Sciences*, *8*(1), 186–189. https://doi.org/10.22271/ortho.2022.v8.i1c.3005

Björkman, F., & Ekblom, Ö. (2022). Physical Exercise as Treatment for PTSD: A Systematic Review and Meta-Analysis. *Military Medicine*, *187*(9–10), e1103–e1113. https://doi.org/10.1093/milmed/usab497

Brehm, M., Beelen, A., Doorenbosch, C., Harlaar, J., & Nollet, F. (2021). Effect of carbon-composite knee-ankle-foot orthoses on walking efficiency and gait in former polio patients. *Journal of Rehabilitation Medicine*, *39*(8), 651–657. https://doi.org/10.2340/16501977-0110

Brehm, M.-A., Ploeger, H. E., & Nollet, F. (2021). Self-reported functional ambulation is related to physical mobility status in polio survivors; a cross-sectional observational study. *Annals of Physical and Rehabilitation Medicine*, *64*(4), 101428. https://doi.org/10.1016/j.rehab.2020.06.007

Brüggenjürgen, B., Braatz, F., Greitemann, B., Drewitz, H., Ruetz, A., Schäfer, M., Seifert, W., Steinfeldt, F., Weichold, C., Yao, D., & Stukenborg-Colsman, C. (2022). Experts' Perceived Patient Burden and Outcomes of Knee-Ankle-Foot-Orthoses (KAFOs) vs. Microprocessor-Stance-and-Swing-Phase-Controlled-Knee-Ankle-Foot Orthoses (MP-SSCOs). *Canadian Prosthetics & Orthotics Journal*, *5*(1). https://doi.org/10.33137/cpoj.v5i1.37795

Campos, K. M. de, Juviniano Quadro, A. A., Falci, M., & Bulle Oliveira, A. S. (2020). Assessment of a fixed-dose combination of l-carnitine + piracetam in the treatment of pain in post-poliomyelitis syndrome. *International Physical Medicine & Rehabilitation Journal*, *5*(6), 233–236. https://doi.org/10.15406/ipmrj.2020.05.00263

Capodaglio, P., Cremascoli, R., Piterà, P., & Fontana, J. M. (2022). Whole-body Cryostimulation: A Rehabilitation Booster. *Journal of Rehabilitation Medicine - Clinical Communications*, *5*, jrmcc00086. https://doi.org/10.2340/jrmcc.v5.2810

Costa, B. (2022). *NMDA Receptor Potentiation and Severe Acute Respiratory Syndrome Treatment*. Authorea, Inc. https://doi.org/10.22541/au.164864550.08969022/v1

Curtis, A., Lee, J. S., Kaltsakas, G., Auyeung, V., Shaw, S., Hart, N., & Steier, J. (2020). The value of a post-polio syndrome self-management programme. *Journal of Thoracic Disease*, *12*(S2), S153–S162. https://doi.org/10.21037/jtd-cus-2020-009

Davis, P. C., Bach, T. M., & Pereira, D. M. (2014). The Effect of Stance Control Orthoses on Gait Characteristics and Energy Expenditure in Knee-Ankle-Foot Orthosis Users. *Prosthetics & Orthotics International*, *34*(2), 206–215. https://doi.org/10.3109/03093641003773189

Dean, E., & Olsén, M. F. (2022). A health and lifestyle framework for the management of post-COVID-19 syndrome based on evidence-informed management of post-polio syndrome: a narrative review. *European Journal of Physiotherapy*, *24*(1), 56–60. https://doi.org/10.1080/21679169.2021.2000150

Digennaro, V., Manzetti, M., Bogucki, B. D. B., & ... (2022). Total knee replacements using rotating hinge implants in polio patients: clinical and functional outcomes. *Musculoskeletal …*. https://doi.org/10.1007/s12306-022-00755-w

Dikalova, A., Aschner, J. L., Kaplowitz, M. R., Cunningham, G., Summar, M., & Fike, C. D. (2020). Combined <scp>l</scp> -citrulline and tetrahydrobiopterin therapy improves NO signaling and ameliorates chronic hypoxia-induced pulmonary hypertension in newborn pigs. *American Journal of Physiology-Lung Cellular and Molecular Physiology*, *318*(4), L762–L772. https://doi.org/10.1152/ajplung.00280.2019

Dluhy, S. D., Hoppe-Ludwig, S., Mummidisetty, C. K., Semik, P., Heinemann, A. W., & Jayaraman, A. (2021). Microprocessor Controlled Knee Ankle Foot Orthosis (KAFO) vs Stance Control vs Locked KAFO: A Randomized Controlled Trial. *Archives of Physical Medicine and Rehabilitation*, *102*(2), 233–244. https://doi.org/10.1016/j.apmr.2020.08.013

Ekstrand, E., Lexell, J., & Brogårdh, C. (2020). Life Satisfaction in Persons with Late Effects of Polio: A Test-Retest Reliability Study. *PM & R: The Journal of Injury, Function, and Rehabilitation*, *12*(10), 997–1002. https://doi.org/10.1002/pmrj.12325

Fontani, V., Coelho Pereira, J. A., Carréra Bittencourt, M., & Rinaldi, S. (2022). Radio Electric Asymmetric Conveyer (REAC) Reparative Effects on Pressure Ulcer (PU) and Burn Injury (BI): A Report of Two Cases. *Cureus*. https://doi.org/10.7759/cureus.27060

Ghelman, R., Akiyama, I. Y., de Souza, V. T., Falcão, J., Orgolini, V., Hosomi, J. K., Quadros, A. A. J., & Oliveira, A. S. B. (2020). A twelve-week, four-arm, randomized, double-blind, placebo-controlled, phase 2 prospective clinical trial to evaluate the efficacy and safety of an anthroposophic multimodal treatment on chronic pain in outpatients with postpolio syndrome. *Brain and Behavior*, *10*(4), e01590. https://doi.org/10.1002/brb3.1590

Gocheva, V., Hafner, P., Orsini, A.-L., Schmidt, S., Schaedelin, S., Rueedi, N., Rubino-Nacht, D., Weber, P., & Fischer, D. (2020). Health-related quality of life, self-reported impairments, and activities of daily living in relation to muscle function in post-polio syndrome. *Journal of Patient-Reported Outcomes*, *4*(1), 59. https://doi.org/10.1186/s41687-020-00226-5

Gunhui, P., Song, J., & Lee, J. (2023). A Case Report of Post-Concussion Syndrome Improved by Korean Medicine Treatment Including Acupotomy. *Journal of Korean Medical Society of Acupotomology*, *7*(2), 226–229. https://doi.org/10.54461/jacupotomy.2023.7.2.226

Gusi, N., Madruga, M., González-González, M. de los Á., Pérez-Gómez, J., & Prieto-Prieto, J. (2022). Health-related quality of life and multidimensional fitness profile in polio survivors. *Disability and Rehabilitation*, *44*(8), 1374–1379. https://doi.org/10.1080/09638288.2020.1804629

Irshad, A., Haider khan, H. M. M., Latif, D., Bugti, M., Ramzan Khan, R., & Bugti, M. K. (2023). Effects of Customized Biomechanical Footwear on Gait and Balance in Individuals with Polio: A Randomized Controlled Trial. *Allied Medical Research Journal*, 15–26. https://doi.org/10.59564/AMRJ/01.02/004

Ismail, I. I., & Salama, S. (2022). A systematic review of cases of CNS demyelination following COVID-19 vaccination. *Journal of Neuroimmunology*, *362*, 577765. https://doi.org/10.1016/j.jneuroim.2021.577765

Kalbarczyk, A., Closser, S., Hirpa, S., Cintyamena, U., Azizatunnisa, L., Agrawal, P., Rahimi, A. O., Akinyemi, O. O., Mafuta, E. M., Deressa, W., & Alonge, O. O. (2022). A light touch intervention with a heavy lift – gender, space, and risk in a global vaccination program. *Global Public Health*, *17*(12), 4087–4100. https://doi.org/10.1080/17441692.2022.2099930

Kalbarczyk, A., Rao, A., Adebayo, A., Decker, E., Gerber, S., & Morgan, R. (2021). The influence of gender dynamics on polio eradication efforts at the community, workplace, and organizational level. *Global Health Research and Policy*, *6*(1), 19. https://doi.org/10.1186/s41256-021-00203-5

Kang, Y., Dillon, K. N., Martinez, M. A., Maharaj, A., Fischer, S. M., & Figueroa, A. (2022). Combined L-Citrulline Supplementation and Slow Velocity Low-Intensity Resistance Training Improves Leg Endothelial Function, Lean Mass, and Strength in Hypertensive Postmenopausal Women. *Nutrients*, *15*(1), 74. https://doi.org/10.3390/nu15010074

Karczewski, D., Siljander, M. P., Larson, D. R., Taunton, M. J., Lewallen, D. G., & Abdel, M. P. (2023). Primary total knee arthroplasty in patients with post-polio syndrome. *The Bone & Joint Journal*, *105*(6), 635–640. https://doi.org/10.1302/0301-620X.105B6.BJJ-2022-0988.R2

Kariyawasam, D., D'Silva, A., & Howells, J. (2021). Motor unit changes in children with symptomatic spinal muscular atrophy treated with nusinersen. *Journal of Neurology.* https://jnnp.bmj.com/content/92/1/78.abstract

Kemenkes RI. (2024). *Perkembangan Situasi Penyakit Infeksi Emerging pada Minggu Epidemiologi ke-7 Tahun 2024.* https://infeksiemerging.kemkes.go.id/weekly-update/perkembangan-situasi-penyakit-infeksi-emerging-minggu-epidemiologi-ke-7-tahun-2024

Khan, A., & Virani, A. (2022). Post-Polio Syndrome in a Primary Care Setting: A Case Report. *Cureus*, *14*(9), e29361. https://doi.org/10.7759/cureus.29361

Koopman, F. S., & Nollet, F. (2024). Post-Polio Syndrome. In *Reference Module in Neuroscience and Biobehavioral Psychology*. Elsevier. https://doi.org/10.1016/B978-0-323-95702-1.00087-7

Laffont, I., Duflos, C., Hirtz, C., Bakhti, K., Gélis, A., Palayer, C., Macioce, V., Soler, M., Pradalier, F., Galtier, F., Jentzer, A., Lozano, C., Vincent, T., & Morales, R. J. (2024). Post-polio syndrome is not a dysimmune condition. *European Journal of Physical and Rehabilitation Medicine*, *60*(2). https://doi.org/10.23736/s1973-9087.23.08158-3

Larsson, L., Degens, H., Li, M., Salviati, L., Lee, Y. il, Thompson, W., Kirkland, J. L., & Sandri, M. (2019). Sarcopenia: Aging-Related Loss of Muscle Mass and Function. *Physiological Reviews*, *99*(1), 427–511. https://doi.org/10.1152/physrev.00061.2017

Latifoglou, E., Çınar, E., Tanıgör, G., & On, A. Y. (2022). Coexistence of fibromyalgia and post-polio syndrome in persons with prior poliomyelitis in Turkey: the relations with symptoms, polio-related impairments, and quality of life. *Disability and Rehabilitation*, *45*(21), 3511–3518. https://doi.org/10.1080/09638288.2022.2127931

Ledesma, S. N., Carroll, J., Burton, P., & Ana, G.-M. (2023). Short-Term Effects of Whole-Body Photobiomodulation on Pain, Quality of Life and Psychological Factors in a Population Suffering from Fibromyalgia: A Triple-Blinded Randomised Clinical Trial. *Pain and Therapy*, *12*(1), 225–239. https://doi.org/10.1007/s40122-022-00450-5

Leggiadro, R. J. (2022). Public Health Response to a Case of Paralytic Poliomyelitis in an Unvaccinated Person and Detection of Poliovirus in Wastewater—New York, June-August 2022. *Pediatric Infectious Disease Journal*, *41*(11), 898–898. https://doi.org/10.1097/INF.0000000000003696

Manzetti, M., Digennaro, V., Di Martino, A., Bordini, B., Benvenuti, L., Ferri, R., Cecchin, D., & Faldini, C. (2024). Survivorship of total knee arthroplasty in poliomyelitis patients: long-term results from the R.I.P.O. registry and single-institution retrospective study. *Archives of Orthopaedic and Trauma Surgery*, *144*(8), 3641–3648. https://doi.org/10.1007/s00402-024-05426-y

Mediarti, D., Rosnani, R., Sukartini, T., Arifin, H., & Kurniawati, Y. (2020). Coverage and factors associated with complete polio vaccination among Indonesian children aged 0–18 months. *Children and Youth Services Review*, *118*, 105399. https://doi.org/10.1016/j.childyouth.2020.105399

Meiner, Z., Marmor, A., Jalagel, M., Levine, H., Shiri, S., & Schwartz, I. (2021). Risk factors for functional deterioration in a cohort with late effects of poliomyelitis: A ten-year follow-up study. *NeuroRehabilitation*, *49*(3), 491–499. https://doi.org/10.3233/NRE-210216

Mercier, M. R., Moore, H. G., Wolfstadt, J. I., Rubin, L. E., & Grauer, J. N. (2022). Outcomes Following Total Hip Arthroplasty in Patients with Postpolio Syndrome: A Matched Cohort Analysis. *The Journal of Arthroplasty*, *37*(9), 1822–1826. https://doi.org/10.1016/j.arth.2022.04.016

Motta, M. P., Juveniano Quadros, A. A., Brito Conti, M. de S., Falci, M., Bulle Oliveira, A. S., Juveniano Quadros, A. A., Brito Conti, M. de S., Falci, M., & Bulle Oliveira, A. S. (2020). L-carnitine+piracetam for fatigue and muscular strength of patients with post-poliomyelitis. *International Physical Medicine & Rehabilitation Journal*, *5*(6), 220–228. https://doi.org/10.15406/ipmrj.2020.05.00261

Motta, M. P., Oliveira, A. S. B., & ... (2023). Improving Strength and Fatigue Resistance in Post-Polio Syndrome Individuals with REAC Neurobiological Treatments. *Journal of Personalized Medicine.* https://www.mdpi.com/2075-4426/13/11/1536

Motta, M. P., Oliveira, A. S. B., André Nogueira, J. A., Vieira de Souza Moscardi, A. A., Favaro, V. M., Simcsik, A. O., Rinaldi, C., Fontani, V., & Rinaldi, S. (2024). Efficacy of REAC Neurobiological Optimization Treatments in Post-Polio Syndrome: A Manual Muscle Testing Evaluation. *Journal of Personalized Medicine*, *14*(10), 1018. https://doi.org/10.3390/jpm14101018

Nogueira, J. A. A., Oliveira, A. S. B., Motta, M. P., de Souza Moscardi, A. A. V., Favaro, V. M., Teixeira, C. M., Simcsik, A. O., Patrizi, M. C., Conde, M. S., Rinaldi, A., Fontani, V., & Rinaldi, S. (2024). Neurobiological modulation with REAC technology: enhancing pain, depression, anxiety, stress, and quality of life in post-polio syndrome subjects. *Scientific Reports*, *14*. https://doi.org/10.1038/s41598-024-68200-5

Obanewa, O. A., & Newell, M. L. (2020). The role of place of residency in childhood immunisation coverage in Nigeria: analysis of data from three DHS rounds 2003–2013. *BMC Public Health*, *20*(1), 123. https://doi.org/10.1186/s12889-020-8170-6

Payra, S., & Mahadevan, K. (2021). Design, Development, and Evaluation of a Bionic Knee-Ankle-Foot Orthosis Retrofit for Walking Gait Normalization. *IEEE Transactions on Medical Robotics and Bionics*, *3*(3), 825–837. https://doi.org/10.1109/TMRB.2021.3093443

Peel, M. M. (2020). Corrigendum to: Epidemic poliomyelitis, post-poliomyelitis sequelae and the eradication program. *Microbiology Australia*. https://www.publish.csiro.au/ma/fulltext/MA20053_CO

Punsoni, M., Lakis, N. S., Mellion, M., & de la Monte, S. M. (2023). Post-Polio Syndrome Revisited. *Neurology International*, *15*(2), 569–579. https://doi.org/10.3390/neurolint15020035

Putananickal, N., Orsini, A.-L., Schmidt, S., Gocheva, V., Rubino, D., Haas, T., Schädelin, S., Deligianni, X., Bieri, O., Fischer, D., & Hafner, P. (2021). Treatment with L-Citrulline in patients with post-polio syndrome: A single center, randomized, double blind, placebo-controlled trial. *Neuromuscular Disorders*, *31*(11), 1136–1143. https://doi.org/10.1016/j.nmd.2021.08.011

Qin, S., Jiao, S., Zang, J., Pan, Q., Guo, B., & Qin, X. (2020). Lower Limb Deformities in Poliomyelitis Sequelae. *Lower Limb Deformities.* https://doi.org/10.1007/978-981-13-9604-5_5

Ruszel, K., & Nieradko-Iwanicka, B. (2020). Is Polio Eradication Possible? *Journal of Education, Health and Sport*, *10*(9), 66–75. https://doi.org/10.12775/JEHS.2020.10.09.007

Samaan, A., & Escalon, M. X. (2021). Joint and Back Pain: Medications and Role of Injection Therapy for Destructive Joint. *Physical Medicine and Rehabilitation Clinics of North America*, *32*(3), 537–546. https://doi.org/10.1016/j.pmr.2021.02.006

Saraswathy, R. (2021). The Genetics of Post-polio Syndrome—An Overview. *Human Viruses: Diseases, Treatments, and Vaccines.* https://doi.org/10.1007/978-3-030-71165-8_35

Shabbir, R. M. K., Saleem, S., Khan, A., Afzal, M. S., Qureshi, U. M., & Ahmed, H. (2020). Hot spots, risk factors, and management of poliovirus in Pakistan. *Journal of Medical Virology*, *92*(11), 2374–2375. https://doi.org/10.1002/jmv.26058

Sherf, R. M., Cantrell, D., Or, K., Marcus, E., Shapira, A., Benbassat, C., Ish-Shalom, S., & Koren, R. (2020). The Risk of Bone Fractures in Post-Poliomyelitis Patients Transitioning to Middle Adulthood. *Endocrine Practice*, *26*(11), 1277–1285. https://doi.org/10.4158/ep-2020-0102

Siddiqui, J., & Bowditch, S. (2023). EE400 Cost-Effectiveness of Cannabidiol (CBD) for the Treatment of Seizures in Patients with Treatment-Resistant Lennox-Gastaut Syndrome or Dravet Syndrome in the Netherlands. *Value in Health*, *26*(12). https://doi.org/10.1016/j.jval.2023.09.666

Silva, E. C. G. e, Lange, B., Bacha, J. M. R., & Pompeu, J. E. (2020). Effects of the Interactive Videogame Nintendo Wii Sports on Upper Limb Motor Function of Individuals with Post-Polio Syndrome: A Randomized Clinical Trial. *Games for Health Journal*, *9*(6), 461–471. https://doi.org/10.1089/g4h.2019.0192

Taine, L., & Cadet, G. (2022). Syndrome post-poliomyélite et efficacité de l'activité physique adaptée en balnéothérapie sur la prévention des fractures per-chute: revue de littérature exploratoire. *Kinésithérapie, La Revue*. https://www.sciencedirect.com/science/article/pii/S1779012322001577

Tetz, K. B., & Schoenbeck, S. L. (2023). Assessing pain—the invisible, long-haul polio symptom. *Nursing2023*. https://journals.lww.com/nursing/fulltext/2023/03000/Assessing_pain_the_invisible,_long_haul_polio.12.aspx

Tigani, D., Ferranti Calderoni, E., Berti, M., Comitini, S., Amendola, L., Pipino, G., & Melucci, G. (2024). Long-Term Results of Third Generation of Rotating Hinge Arthroplasty in Patients with Poliomyelitis. *Prosthesis*, *6*(4), 853–862. https://doi.org/10.3390/prosthesis6040061

Tillet, F., Bochatey, E., Pérez Alamino, L., & Lopreite, F. A. (2022). Lavado con povidona yodada diluida en el reemplazo articular de cadera y rodilla para prevenir infecciones: estudio retrospectivo comparativo. *Revista de La Asociación Argentina de Ortopedia y Traumatología*, *87*(5), 619–625. https://doi.org/10.15417/issn.1852-7434.2022.87.5.1530

Topaloğlu, M., Ketenci, A., Baslo, B., & Şahinkaya, T. (2022). The effect of adding whole-body vibration exercises to home exercise program on muscle strength in patients with post-polio syndrome. *Turkish Journal of Physical Medicine and Rehabilitation*, *68*(1), 117–125. https://doi.org/10.5606/tftrd.2022.7063

Topaloglu, M., Sarikaya, D., Peker, A., Senturk, Y. E., Terlemez, R., Cetin, B. U., Oge, A. E., & Ketenci, A. (2024). Differentiation of Post-Polio Syndrome from Prior Poliomyelitis Sequela by Assessing Paraspinal Muscle Involvement in Magnetic Resonance Imaging. *Journal of Clinical Medicine*, *13*(16), 4828. https://doi.org/10.3390/jcm13164828

Upadhyaya, G. K., Patralekh, M. K., Jain, V. K., Iyengar, K. P., Gautam, D., Vaishya, R., & Malhotra, R. (2021). Total Hip Arthroplasty in Patients with Post polio Residual Paralysis: A Systematic Review. *The Journal of Arthroplasty*, *36*(6), 2239–2247. https://doi.org/10.1016/j.arth.2021.01.046

WHO. (2024). *Circulating vaccine-derived poliovirus type 2 (cVDPV2) - Indonesia*. https://www.who.int/emergencies/disease-outbreak-news/item/2024-DON500

Wilkinson, A. L., Diop, O. M., Jorba, J., Gardner, T., Snider, C. J., & Ahmed, J. (2022). Surveillance to Track Progress Toward Polio Eradication — Worldwide, 2020–2021. *MMWR. Morbidity and Mortality Weekly Report*, *71*(15), 538–544. https://doi.org/10.15585/mmwr.mm7115a2

Zang, J., Feng, L., Wang, J., Wang, X., & Li, K. (2023). Should more attention be paid to polio sequela cases in China? *Frontiers in Public.* https://doi.org/10.3389/fpubh.2022.1076970