

INTEGRATED MOVEMENT-BASED INTERVENTIONS FOR FUNCTIONAL HEALTH: BRIDGING PHYSIOTHERAPY, ORTHOPEDIC REHABILITATION, SPORTS PERFORMANCE, PHYSICAL EDUCATION, AND YOGA PRACTICE

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ABSTRACT

The use of movement-based interventions is a growing body of knowledge and is foundational to enhancing functional health, rehabilitation outcomes, physical performance, and long-term health and well-being. This comprehensive review provides a synthesis of the evidence related to physiotherapy, orthopedic rehabilitation, sports performance, physical education and yoga practice to create a holistic understanding of functional health through movement. The review highlights biomechanics, motor learning, physical literacy, and mind-body science as key theoretical foundations supporting movement quality, adaptation, participation, and self-regulation. Evidence across clinical and performance domains indicates that movement-based approaches contribute to postoperative recovery, musculoskeletal rehabilitation, athletic monitoring, lifelong physical activity, yoga-based health benefits, and healthy aging. Shared mechanisms include musculoskeletal adaptation, neuromuscular regulation, mobility improvement, balance enhancement, injury prevention, pain modulation, psychological well-being, and quality of life improvement. The review also emphasizes the need for translational frameworks that connect rehabilitation, performance enhancement, health promotion, and digital delivery models. Implementation across children, adolescents, adults, athletes, clinical populations, and older adults requires population-specific adaptation and interprofessional collaboration. Even with these emerging findings, the field is still hindered by the variability of research, protocol, outcome measures, and the limited validation of technology-assisted and individualized interventions. Integrated Movement-Based Interventions promise a potential avenue for advancing functional independence, rehabilitation success, healthy aging, and human performance.

KEYWORDS: Movement-based interventions, Functional health, Physiotherapy, Orthopedic rehabilitation, Yoga practice

1. INTRODUCTION

Technology has become wonderfully advanced and made life more convenient and productive for modern men, women and children, but has also had a negative impact on the amount of habit-forming physical activity that is done. More time spent on digital devices, automation, and sedentary work has significantly limited opportunities for physical activity amongst all populations, posing major threats to physical health and functional well-being [1]. Thus, physical inactivity has become one of the most prevalent modifiable risk factors for health, and has been shown to impact the prevalence of chronic diseases, disability, and premature mortality on a global scale [2]. The lack of physical activity has a high cost on health-care systems, beyond the cost of inaction to the individual, by increasing treatment costs, the use of resources and the long-term management of avoidable health conditions [3].

There is a growing appreciation of functional health as an important outcome in clinical and community settings that reflects a person's ability to carry out daily activities efficiently and independently. As a person gets older, and as chronic diseases develop, the ability to function becomes more significant, and is often connected to physical decline, limitations of mobility and diminished quality of life [4]. This has led to the development of strategies to improve movement capacity and preserve physical function being central to contemporary healthcare and rehabilitation practices. Movement-based interventions are a general class of interventions that use movement to enhance performance, functional capacity and health. These include therapeutic exercise, motor control training, balance exercises, flexibility exercises, and other modalities focused on movement that address physical and psychosocial outcomes [5]. The evidence base for these strategies has grown significantly over the last few years, with their effectiveness shown for a variety of populations, with respect to improvements in strength, mobility, balance and functional fitness. Of these interventions, movement-based

mind–body practices have become more prevalent and of interest due to the ability to positively impact both physical and psychological aspects of health. There is meta-analytic evidence that these methods can have a significant impact on physical fitness and functional performance, particularly with older adults [6].

As well as yoga becoming mainstream in the fitness world, it is also being incorporated into healthcare and rehabilitation. Yoga has traditionally been considered as an integrated discipline focusing on physical postures, breathing exercises and mindful awareness, but it has become a popular part of rehabilitation and sports medicine practice to facilitate recovery, promote mobility, prevent injuries and enhance overall function [7]. Similarly, physiotherapy, orthopedic rehabilitation, and sports medicine have increasingly taken up a holistic approach that is movement-oriented in an effort to achieve more than merely alleviating symptoms [8].

Although a number of disciplines have gained in individual support with evidentiary bases, the literature is largely scattered across professional domains. However, physiotherapy, orthopedic rehabilitation, sports performance training, physical education and yoga are often studied in isolation, and the principles and complementary mechanisms of these fields, as well as their combined effect on functional health, remain unclear. However, a synthesis that integrates these disciplines is presently missing, and knowledge gaps exist on how movement-based interventions could be considered in relation to a functional health framework.

The goal of this review is to assess critically and combine data from physiotherapy, orthopedic rehabilitation, sports performance, physical education and yoga practice to gain a holistic understanding of movement-based interventions for functional health. The purpose of this review is to create a unified vision that can inform clinical practice, health promotion, rehabilitation and human performance across a variety of populations, by highlighting common mechanisms, outcomes, and opportunities for interprofessional application.

2. REVIEW METHODOLOGY

The narrative approach of this comprehensive review was adopted to select an appropriate method in synthesizing evidence related to movement-based interventions in physiotherapy, orthopedic rehabilitation, sports performance, physical education and yoga practice. The relevant literature was identified from peer-reviewed journals, academic books, systematic reviews, scoping reviews, conceptual papers, randomized trials and narrative reviews related to the field of functional health, rehabilitation, movement science, exercise and mind–body practice. Studies were included if they included integrated movement-based care as a theoretical basis, clinical application, mechanism of action, implementation context, or future directions. The evidence was sorted thematically rather than statistically, since the literature included was varied, with each having different populations, interventions and outcomes. Results were compiled and analyzed for common principles, mechanisms, applications and research needs.

3. Theoretical Foundations of Integrated Movement-Based Interventions

There is a wide spectrum of theories to support the use of integrated movement-based interventions which provide a linkage between movement and functional health, physical performance, rehabilitation and long-term wellbeing. These interventions are not from one discipline, but rather, they are a result of the convergence of biomechanics, motor learning, physical literacy and mind–body sciences. Combined, these views lead to a thorough understanding of the development, control, adaptation and maintenance of movement throughout the life span and with their varying health conditions. Biomechanics is the science that provides the basis for understanding human movement. Movement is a result of the coordinated interaction of muscles, joints, connective tissue and external forces, and must be continually regulated for stability and movement. Dynamic balance is a key component of this process as it enables a person to control their body to move successfully in a changing environment and task [9]. The progress in biomechanical modelling also contributes to the understanding of the behavior of the movement, allowing a detailed analysis of the interactions between the musculoskeletal system, the transmission of the forces and the strategies used for the movement under different functional circumstances [10]. The innovations have made it possible to incorporate the concepts of biomechanics into areas such as rehabilitation, athletic performance, and movement analysis, thus providing information on efficient movements, injury causation, and effective functioning [11].

Whilst biomechanics has developed a good understanding of the processes by which movement is produced, it doesn't explain the processes of how movement skills are acquired and developed. Motor learning theory, which focuses on the relatively permanent changes in movement capability resulting from practice and experience, is used to address this process. The motor learning principles of repetition, feedback, task specificity and progressive adaptation have been crucial in the design of effective movement-based interventions, helping to promote improvements in the quality of movement and functional outcomes [12]. Modern views contend that motor learning is an active and dynamic process that relies on sensory feedback, prediction, error correction and continual adaptation. By these means, the person learns more efficient ways to move that can be generalized to functional tasks and real-world situations [13]. The concept of physical literacy is more than a theory of movement, it's about skills and training, and having a mindset of embracing a lifelong approach to movement and physical activity. Physical literacy combines movement competence with motivation, confidence, knowledge and understanding, as the development of movement competence is important, but it is also important to have the psychological aspects in order to be able to participate in physical activity for a long time. This approach has been conceptualized as a life long skill essential for health, social engagement and functional independence and creates a strong connection to the health of populations and its capacity to move [14].

The theoretical background of integrated movement-based interventions also incorporates a view of mind–body sciences, which recognize that there is a connection between physical, cognitive, emotional and behavioral processes. This way,

moving is not just a mechanical process but a process that impacts several aspects of human functioning. This is the principle of Yoga exemplified through combining physical postures, breath control, awareness and mindfulness and body awareness. They can be used in conjunction with more traditional rehabilitation- and exercise-based approaches and have positive effects on self-regulation, body awareness, tolerance for psychological stressors and function. [15]

Theories, when combined show that human movement behavior is a complex phenomenon which is affected by mechanical, neurological, behavioral and psychosocial factors. The new conceptual framework that facilitates movement interventions based on the principles of biomechanics, motor learning, physical literacy and mind/body concepts supports the implementation of the interventions. From this holistic base, holistic strategies can be developed, which may result in improved functional health, rehabilitation and human performance optimization for a variety of populations and throughout the lifespan. The theoretical convergence of biomechanics, motor learning, physical literacy and mind–body science is summarized in Table 1.

Table 1. Core Theoretical Foundations of Integrated Movement-Based Interventions

Theoretical domain	Core principle	Functional relevance	Linked intervention focus	Key references
Biomechanics	Force, alignment, balance, and movement efficiency	Improves movement quality and reduces mechanical overload	Gait training, posture correction, mobility work	[9–11]
Motor learning	Practice, feedback, repetition, and adaptation	Supports skill acquisition and functional recovery	Task-specific training, progressive rehabilitation	[12,13]
Physical literacy	Competence, confidence, motivation, and knowledge	Promotes lifelong physical activity participation	Physical education, community movement programs	[14]
Mind–body science	Breath, awareness, self-regulation, and attention	Enhances physical and psychosocial functioning	Yoga, mindful movement, breath-based practice	[15]

4. Evidence Across Clinical and Performance Domains

There has been a significant growth in the implementation of movement-based interventions in health care, rehabilitation, sport, public health and wellness environments. Although there are variations in the population groups served and the different ways in which they are implemented, the overall goal of all these interventions is to improve functional capacity by providing structured movement. Research from various disciplines confirms that movement-based methods can be effective in recovery, performance, lifelong physical activity and overall health, thus showing that there is a wide applicability of these approaches to functional health. In clinical rehabilitation, physiotherapy is still a fundamental approach to movement for patients who have undergone orthopedic surgery and patients with musculoskeletal conditions. The data from TES pathways suggests that the physiotherapy interventions that are provided throughout the pathway (from prehabilitation in preparation for surgery, to functional restoration in the post-surgical period) can enhance recovery from TES and have a significant role in delivering cost-effective healthcare [16]. The results highlight the importance of starting intervention preparation early and progressing rehabilitation, and provide support for the need to restore functional independence and to use resources optimally.

Movement is not just for functional recovery, but also to affect the biological processes of tissue healing and adaptation. Post-traumatic musculoskeletal lesions have been studied to show how rehabilitation interventions interact with mechanisms of regeneration and plasticity to affect muscle remodeling, neuro-muscular recovery and long-term function [17]. This is why the rationale behind a movement-based rehabilitation approach goes beyond being a compensatory solution and is an important aid in restoring physiological function and functional capacity. In sports science, technology has progressed to make it easier to analyse and optimise human movement. Over the past few years, the invention of complex simulation models of movement behavior has made it possible to perform biomechanical analysis of the performance and to predict the outcome of the movement and develop more individual training strategies [18]. These trends have evolved over time and are now being helped by computational tools for the analysis and design of movement interventions.

Development of sports practice based on evidence has been further reinforced by the use of wearable technologies. Physiological and biomechanical parameters can be continuously measured with wearable sensors and the internal workload responses and external demands of the movement during training and competition can be assessed [19]. These technologies are able to offer crucial information about fatigue management, training adaptation, and injury prevention, demonstrating the importance of objective movement monitoring in promoting athletic performance whilst also protecting the health of the athletes, and highlighting the added value of objective movement monitoring in these fields. Apart from sport, there is a need for movement interventions for public health and policy interventions to encourage participation in physical activity across the life course. The Physical Activity and Sport Participation Framework highlight the importance of providing opportunities, policies and supportive environments to nurture participation in physical activity over the long-term throughout childhood and older ages [20]. This perspective lends support to the idea that Movement-Based Interventions can be applied outside of the clinical environment and more should be provided in the community, educational and recreational environments to develop and promote functional health throughout the lifespan.

Yoga has received a lot of scientific interest, particularly due to its multidimensional effect on human functioning among complementary movement practices. A recent scoping review suggests that there may be neural, cognitive, psychological and physiological adaptations in adults when they practice yoga for long periods of time [21]. The results indicated that yoga has a wider impact on one's health than just flexibility and physical fitness; it produces effects on other areas of health that are important for functional ability and wellbeing. Movement-based interventions are especially important for older adults as their age-related loss of strength, balance, mobility and endurance can impact their independence and the quality of their life. Older people who are physically active regularly have been shown to have higher functional capacity, less fall risk, greater mobility and better overall health status [22]. This evidence is supportive of the incorporation of structured movement programmes into strategies for healthy ageing/disability prevention.

Overall, the results from the rehabilitation, sports science, public health, yoga practice, and geriatric care fields show the flexibility and efficacy of movement-based interventions. Although the intent and the ways in which movement can be applied to this domain are different, the evidence is always consistent and supports the role of movement as a major factor to functional health, including as a common strategy for rehabilitation, performance enhancement, disease prevention, and lifelong well-being. Table 2 shows the key evidence domains associated with the use of movement-based interventions for rehabilitation, performance, public health and healthy aging.

Table 2. Evidence Across Clinical, Performance, and Community Domains

Domain	Target population	Intervention emphasis	Main functional contribution	Key references
Orthopedic rehabilitation	Surgical and musculoskeletal patients	Prehabilitation, postoperative physiotherapy, functional restoration	Recovery, mobility, independence	[16,17]
Sports performance	Athletes and active individuals	Digital modeling, workload monitoring, training optimization	Performance enhancement and injury risk management	[18,19]
Public health and physical education	General population across the lifespan	Participation frameworks and active lifestyle promotion	Lifelong movement engagement	[20]
Yoga-based practice	Adults and wellness populations	Postures, breathing, mindfulness, long-term practice	Neural, cognitive, psychological, and physiological benefits	[21]
Geriatric exercise	Older adults	Strength, balance, endurance, and mobility training	Fall prevention, independence, healthy aging	[22]

5. Mechanisms of Action and Shared Outcomes

Integrated movement-based interventions have been demonstrated to have a positive impact on health and performance outcomes via several physiological, neuromuscular, functional, and social/psychosociological pathways. While there are distinct differences in the techniques employed, physiotherapy, rehabilitation, sports training, physical education and yoga often have similar effects through a common mechanism of action that includes musculoskeletal adaptations, efficient movement, improved mobility, pain modulation, psychological health and quality of life enhancement. Knowing these mechanisms offers an understanding of why movement-based approaches are successful in a variety of populations and settings. The promotion of musculoskeletal adaptation is one of the main mechanisms responsible for the effect of movement-based interventions. The purpose of structured movement programs is to stimulate changes within the muscles, connective tissue, and nervous system that enhance strength, endurance and function. Research also supports the benefits of targeted movement training programs in provoking adaptive responses in musculoskeletal health; for example, the evidence demonstrates substantial gains in musculoskeletal health among inactive women who participated in a hybrid neuromuscular training program [23] when they were overweight and obese. These adaptations are crucial in future functional movements and for competence in moving.

Neuromuscular control is also affected by movement-based interventions, as a combination of physical activity and cognitive and sensory processing. Mind-body movement practices like yoga, tai chi and qigong integrate controlled movement, posture awareness, breathing regulation and focused attention, providing an opportunity to enhance movement efficiency and to manage physical symptoms. These techniques have been shown to have beneficial effects on symptom management and functional recovery in individuals with back pain, beyond that of physical exercise alone, indicating that coordinated neuromuscular and psychosocial mechanisms play a role in symptom management and functional recovery [24]. Another typical improvement that can be achieved in movement disciplines is increased mobility and functional movement. Better mobility is frequently provided by challenging balance, coordination, gait and motor control. A new training program targeted to adolescents with movement disorders was found to have encouraging results in functional parameters related to mobility, suggesting that specific movement training can assist functional performance even in

adolescents with broad movement disabilities [25]. These results corroborate the importance of movement-based training to increase independence and participation in daily activities.

Balance and movement control are key factors when looking at functional health, especially in the elderly. Creative dance interventions have demonstrated positive effects on older adults in physical fitness, functional balance and mobility control [26]. The benefits can be the integration of multiple movement patterns, sensory integration and cognitive engagement that are experienced across dance activities, as movement-based programmes can be focused on several areas of functional performance. Another mechanism to impact health outcomes is by preventing injury. Structured warm-up and preparatory movement programme aim to enhance movement quality, physical fitness and performance capacities, and to decrease risks of injury. There remains a need for further research, but the existing evidence for school-based injury prevention programs suggests that targeted movement interventions may positively influence selected fitness and performance factors during adolescence, which can lead to the development of safer and more effective movement behaviors [27]. These adaptations can help reduce the barriers of physical dysfunction and injury and help to ensure participation in physical activity in the long term.

Many movement-based therapies share pain modulation as a shared therapeutic effect. Psychological and behavioral principles are increasingly included in contemporary movement interventions along with physical training to help treat the multidimensional nature of pain. Psychologically informed mindful movement physical therapy promotes the simultaneous treatment of both physical and psychological aspects of pain, using a unique combination of movement practice, mindfulness and cognitive strategies [28]. This view mirrors the fact that more and more it is understood that biomechanical, cognitive and emotional aspects of movement-based care need to be dealt with simultaneously. The other benefit of movement-based interventions is for psychological well-being. There are connections between the processes of embodiment, emotional expression, social engagement and mindful engagement with movement, and dance-based movement programs are associated with processes of mental well-being [29]. These results validated the concept that movement is beneficial not only for physical function, but also for other psychological parameters which affect adherence, motivation and quality of life. All these are linked to enhanced physical function and reduced pain, increased confidence in moving, psychological well-being, and enhanced health-related quality of life. Besides educational programmes, there are pain outcomes and perceived QOL benefits for patients with established spinal osteoporosis with movement-oriented interventions in a short- and long-term follow-up period [30]. This indicates that movement interventions can provide valuable outcomes that go beyond physiological metrics to include well-being and functioning in daily life.

Together, these mechanisms illustrate movement interventions' multi-dimensional pathways to positive outcomes. The processes of musculoskeletal adaptation, neuromuscular regulation, enhancement of mobility, improvement in balance, injury prevention, pain management, psychological well-being, and improvement of quality of life are interconnected and linked to functional well-being. These results across the various models of intervention also highlight the importance of incorporating movement into clinical, rehabilitative, performance and education contexts. The mechanisms and outcomes common to all approaches to movement are presented in Table 3.

Table 3. Shared Mechanisms and Outcomes of Movement-Based Interventions

Mechanism	Representative intervention	Primary outcome	Functional health implication	Key references
Musculoskeletal adaptation	Hybrid neuromuscular training	Strength, endurance, tissue adaptation	Improves physical capacity	[23]
Neuromuscular regulation	Yoga, tai chi, qigong	Motor control and symptom reduction	Supports pain-related functional recovery	[24]
Mobility enhancement	Targeted training and dance-based movement	Mobility, balance, coordination	Improves independence and movement confidence	[25,26]
Injury prevention	Warm-up and mobility programs	Fitness and movement preparedness	Reduces injury-related participation barriers	[27]
Psychosocial regulation	Mindful movement and dance-based interventions	Pain care, mental well-being, quality of life	Supports adherence and whole-person health	[28–30]

6. Integrated Models and Translational Frameworks

The importance of movement as a key component of functional health has led to the creation of integrated models, which span across disciplines. Traditionally, physiotherapy, orthopedic rehabilitation, sports performance, physical education, and yoga have developed into separate areas with specific goals and techniques. However, there is growing evidence, especially from the current era, that more comprehensive and personally relevant perspectives to health, rehabilitation, and performance can be achieved through translational frameworks that involve shared movement principles that link these domains. The underlying principle of movement-based frameworks is that human movement is a coordinated, purposeful process with the interaction of physical, cognitive, and environmental factors. The underlying principles of movement focus on alignment, balance, coordination, efficiency and adaptability, which are key qualities of functional

movement. These are the principles that can be applied in rehabilitation, athletic development, education and wellness programs, as well as with greater integration across the disciplines of movement [31]. This shift in thinking from treatment to movement as a human skill that moves over time and is flexible, has implications for the practice, design and evaluation of programs and practices. Translation of movement science to clinical practice has helped to generate integrative models in physiotherapy. Integrative Physical Therapy is a holistic method of care that takes into account all of the factors that may impact movement and health: (physical, psychological, behavioral and social). This is not focused on individual symptoms but rather a multi-modal approach with several, well-supported, treatments to maximize functional recovery, self-management and long-term outcomes [32]. From this perspective, movement-based interventions are integrated into a comprehensive approach to care, which considers the influence of different factors on health outcomes.

The present developments in musculoskeletal rehabilitation, which combine physical activity with integration of the mind-body aspects, also illustrate an integrative approach. Bodies that incorporate the idea of body awareness, breathing regulation, and cognitive engagement, along with the usual exercise know that quality of movement depends on both the physical and the psychological processes. Combining body, mind, and breath to the rehabilitation process has been suggested as a way to facilitate sustainable recovery, enhance movement confidence, and enhance long-term functional resilience [33]. These models illustrate how, and by how much, the therapeutic benefits of the different treatments have been combined in a single "movement therapy" approach. Integrated frameworks are evident in the continuum between rehabilitation and performance enhancement, as well. The rules that have been developed in the past relating to healing injury appear to be increasingly being applied in sports to enhance sporting performance or to reduce the likelihood of injury. For instance, flexibility and mobility training based on yoga-based approaches has been integrated into sports-specific injury prevention programs, and how movement strategies are applied can be transferred across clinical and sports settings [34]. The common denominator is the need to make movement more efficient, functional and physically ready, whether it is for recovery or performance improvement.

Integrated movement models also take a life span approach, acknowledging the importance of movement as a determinant of health across the lifespan from early adulthood to older age. Routine physical activity is a factor in sustaining musculoskeletal function, mobility and health throughout life. The evidence base for maintaining movement behaviors into adulthood and beyond as a way to maintain functional independence and to minimize the burden of age-related decline is strong [35]. Hence, the focus of translational frameworks is increasingly on the continuity of movement participation and not on rehabilitation, exercise and health promotion as separate processes. Effective implementation of integrated models of movement is key to interprofessional working. Physiotherapists play a key role in this process, having skills in assessment, rehabilitation, movement education, health promotion and movement restoration. Physiotherapy has expanded beyond patient treatment in modern times to include the education of patient care, prevention of problems, working cooperatively with other professionals, and encouraging patients' life-long movement habits [36]. Physios work in a wide range of scopes and are as much facilitators of the translation of movement science to clinical practice in health, community, education and sports contexts.

These frameworks are connected and translational, and in concert serve to foster a more comprehensive understanding of functional health. They link the basic principles of movement to rehabilitation, performance enhancement, health promotion and lifelong physical activity, and offer a seamless framework whereby movement-based interventions can be applied in a variety of populations and environments. These models provide a useful avenue to connect previously disjointed disciplines and to promote a unified strategy to health and human function through movement. The integration of physiotherapy, orthopedic rehabilitation, sports performance, physical education, and yoga has been demonstrated in a multi-disciplinary manner using common principles of movement and intervention strategies as shown in Figure 1.

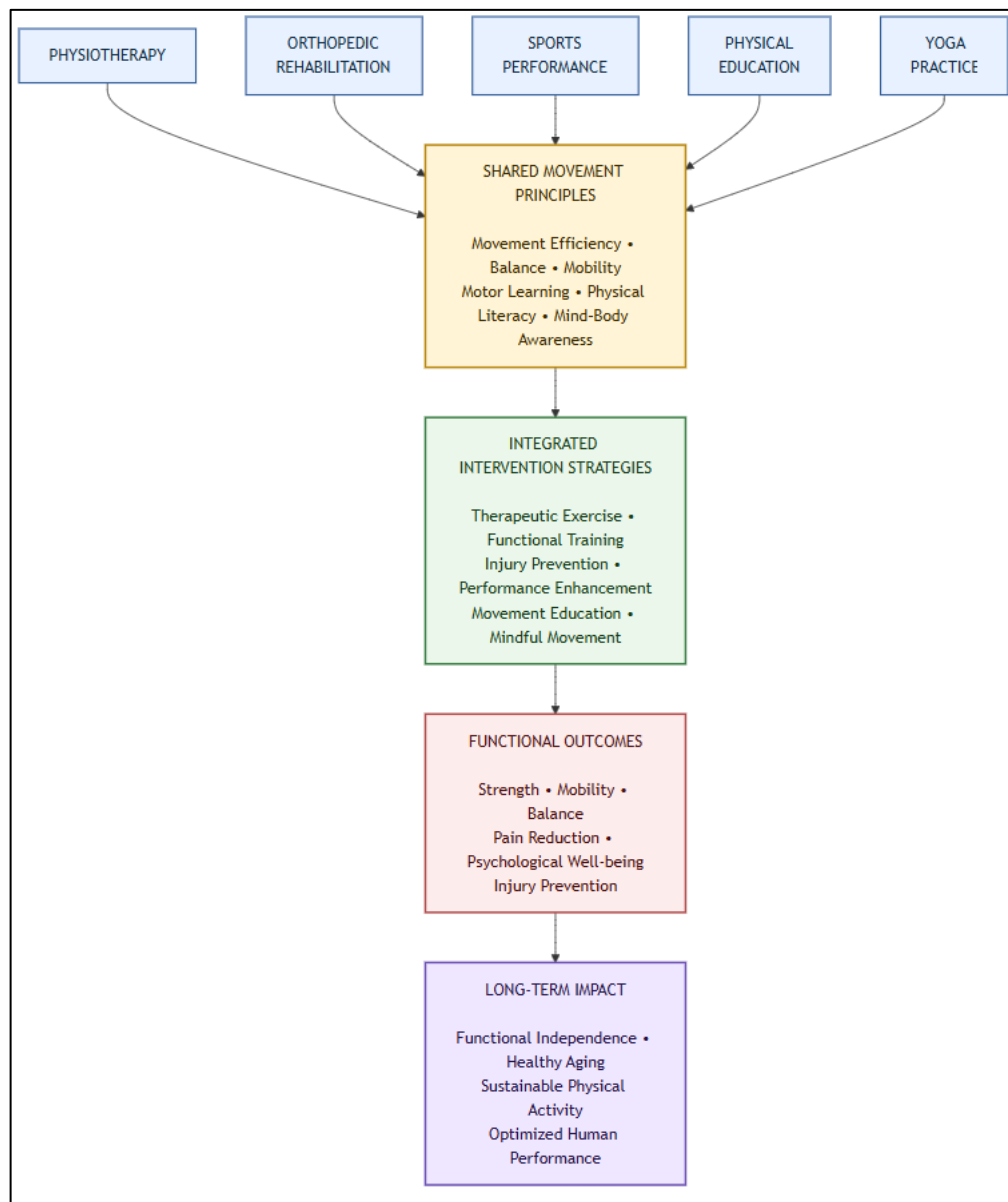


Figure 1. Integrated Translational Framework for Movement-Based Functional Health

7. Implementation Across Populations and Settings

There is a need for adaptation to the specific needs, capacities, and contexts for different populations to implement movement-based interventions successfully. The principles of movement are the same, but the intervention strategies need to be adapted based on the age, health status, functional goals and participation settings. Studies on movement-based interventions in clinical practice, rehabilitation, sports performance and digital health have shown that it is effective across a variety of populations, across the lifespan, supporting functional health. Early implementation during childhood and adolescence is especially important since competency with moving developed during this period can have an impact on lifetime physical activity and functional health. The Functional Movement Screen (FMS) has become a more popular assessment tool to detect dysfunctional movement patterns and asymmetries in young populations. The detection of deficits in movement at a young age could aid in the development of strategies that improve the quality of movement, reduce the chance of injury, and support proper physical growth [37]. This strategy recognizes that it is essential to establish proper movement habits early on in life to avoid future difficulties with movement.

The movement-based practices in health have increased not only as a prescription for movement, but also as a practice of movement. With the increasing acceptance and popularity of yoga, it has become increasingly common in physical therapy to utilize yoga as a means to add flexibility, balance and breathing control into the traditional rehabilitation process. The introduction of yoga in clinical physiotherapy practice is a case in point of the growing emphasis on a holistic approach to movement in which social and psychological issues of health are also taken into account [38]. This integration will add resources for the clinician to use in functional recovery and patient-centered care. Movement-based interventions have also been utilized in sport to enhance performance and psychological resilience and are becoming more common in sport populations. Yoga is also one of the recommended mindful movement activities to help alleviate stress-related issues in athletes. Yoga-derived mindfulness training may be helpful in self-regulation and in lowering indicators of post-traumatic

stress reactions, and improving athletic performance and recovery [39]. The outcomes correspond with the general application of movement practices to the health of athletes, both physically and mentally.

Another crucial area where the importance of movement-based treatments becomes even greater is orthopedics. Recently, physiotherapy in orthopedics became more centered around restoration of movement and rehabilitation by prescribing evidence-based orthopaedic exercises. The main goal of the listed measures below is to solve problems related to mobility, strength and physical functioning to make it possible to resume normal activity and participation [40]. The use of rehabilitation through movement in the orthopedic field shows the need for individualized rehabilitation strategies for achieving functional outcomes. A good example of such a structured movement intervention to enhance recovery outcomes is postoperative rehabilitation. Exercises and movement-based rehabilitation programs have proved useful after spinal surgeries to improve functional capabilities and promote the recovery process. Exercises and movement based rehabilitation programs have proved useful after spinal surgeries to improve functional capabilities and promote the recovery process.. There is systematic evidence that suitably planned rehabilitation activities have positive impacts on post-surgical outcomes in adults, and can aid in the re-establishment of physical function [41]. The results support the significance of movement as an integral part of the surgical recovery processes.

Yoga has also been embraced beyond the realm of healthcare and rehabilitation, into health promotion and sports performance. New research is emerging, which supports the development of evidence-based frameworks to facilitate the integration of yoga in health enhancement and athletic preparation programs. Yoga is regarded as a multi-faceted movement activity that can play a role in flexibility, mobility, recovery, mental concentration, and physical performance, and these frameworks acknowledge this [42]. As yoga becomes more widely adopted in varied environments, it's evident that it's flexible and can be implemented for a variety of purposes and population needs. Movement-based interventions can be delivered in a novel (non-face-to-face) environment with the use of digital technologies. Exergames and exercise platforms with digital support are methods of promoting exercise and health-related engagement for a variety of ages that are interactive in nature. These technologies could be used to improve accessibility, motivation and participation by integrating movement in digital processes, and broaden the range of movement-related health promotion strategies [43]. With the ongoing development of digital health, the use of technology-delivered movement interventions could become a growing solution to tackle barriers to physical activity participation.

The movement-based interventions implemented across populations and settings overall illustrate the flexibility and wide applicability of these interventions. Movement-based strategies promote functional abilities and wellness across all clinical, youth development, orthopedic, athletic, yoga, and digital health practice settings. It is crucial to tailor interventions to the attributes and needs of particular groups to achieve the greatest impact, if sustainable health gains are to be achieved. In Figure 2, the evidence of movement-based interventions is shown across different populations and settings and how these interventions contribute to functional health across different age groups.

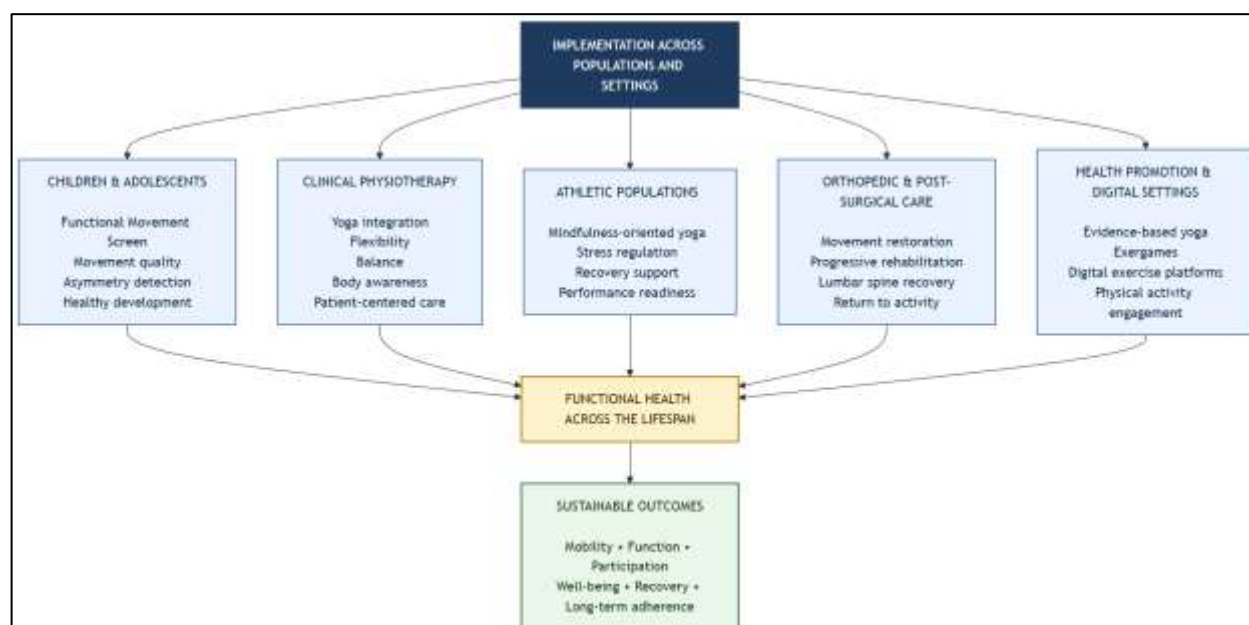


Figure 2. Population- and Setting-Specific Implementation Pathways of Movement-Based Interventions

8. Current Challenges, Knowledge Gaps, and Future Research Directions

There are still critical conceptual, methodological, technological and translation challenges to integrated movement-based interventions. Though physiotherapy, orthopedic rehabilitation, sports performance, physical education, and yoga have similar movement-focused objectives, the evidence base is split between each of the disciplines. This disintegration reduces the ability to create a coherent model of how the various movement approaches interact, complement and work together as a whole to achieve functional health outcomes. The need for a well-defined interdisciplinary approach between traditional movement practices and state-of-the-art scientific techniques is one of the main obstacles. Both yoga and sports

science have a focus on improving human performance, resilience and self-regulation, but tend to be looked at in isolation, both the theoretical and methodological aspects. However, recent studies have shown the need for incorporating traditional Yoga practices into modern sports science to create a holistic approach for human optimization [44]. The integration of such aspects as physiological, biomechanical, psychological and behavioral aspects of movement practice could potentially help in the filling of this gap; however, further empirical validation is needed. Another key focus of opportunity and uncertainty is technology-based rehabilitation. Tele-physiotherapy has helped to improve access to physiotherapy rehabilitation services, especially for those who are unable to access or have made their physiotherapy sessions difficult due to geographic access, mobility or other healthcare access. Nevertheless, practical application of sensing technologies in tele-rehabilitation is still hindered due to measurement errors, ease of use, patient compliance, meaning of the measurement data, privacy and integration of the clinical application [45]. Future studies are needed to identify the standardization and testing of wearable sensors, motion capture systems and remote monitoring technologies for safe and effective assessment of movement in a non-clinical setting.

Another priority for further research in integrated movement-based care is personalization. New digital systems try to synthesize recommendations for yoga, physiotherapy exercises and personalized fitness advice to create personalized recommendation platforms. Future scenarios envision a prescription for intervention tailored to the user's characteristics, functional needs, movement restrictions and health objectives [46]. However, the evidence available is still limited and the implications of using algorithm based recommendations for movement on clinical validity, safety, effectiveness and long-term adherence should be investigated.

There are also some methodological shortcomings that hinder efforts in this area. A lot of studies adopt inconsistent intervention protocols, outcome measures, follow-up periods and population-specific designs that limit the comparability of the studies across disciplines. However, there is some disagreement about the functional outcomes to be emphasized for the assessment of integrated movement-based interventions. Standardized assessment batteries which encompass physical function, movement quality, pain, psychological well-being, adherence, quality of life and participation outcomes should be used in future research. The second gap is related to implementation in real-life contexts. The ability to successfully transfer interventions to clinical settings, schools, sports programs, community and digital health platforms greatly influences the effectiveness of movement-based interventions. The implementation of integrated interventions in a sustainable way across different populations should therefore also include pragmatic trials, implementation science frameworks, cost-effectiveness analyses and interprofessional care models.

Future studies should build upon the evidence related to the specific discipline and move towards an integrated science of functional health in the context of movement. To better define movement-based interventions as a common, evidence-informed strategy for rehabilitation, health promotion, athletic development, and functional wellness throughout the lifespan, greater conceptual clarity, methodological rigor, and validated digital tools and models for intervention are required.

9. CONCLUSION

This review showcases how movement is a key and integrative factor of functional health within the context of rehabilitation, sports, education, and mind-body practice. Both physiotherapy and orthopedic rehabilitation, sports performance training, physical education, and yoga offer similar mechanisms, such as enhanced movement efficiency, neuromuscular control, mobility, balance, pain modulation, psychological well-being, and continuing participation as evidenced by the literature reviewed. These approaches can be considered as the different elements of a more comprehensive movement-based approach. The synthesis also suggests that integrated interventions could be useful throughout the lifespan, in the early movement development in children and adolescents, and in functional preservation in older adults. Clinical and community applications also indicate that movement-based approaches can be used to aid recovery and injury prevention, to enhance physical performance and to promote long-term quality of life. However, there are still many limitations to the field, including inconsistent evidence, intervention designs that are not standardized across studies, and inconsistent measures of outcome, as well as limited validation of digital and personalized delivery models. Future work needs to focus on interdisciplinary models, standardized evaluation instruments, pragmatic trials and technology-assisted models, which can be safely scaled up and implemented in real-world settings. In conclusion, movement-based interventions that are integrated are an attractive approach to promote functional independence, rehabilitation outcomes, healthy aging, and human performance.

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