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Biomechanical and Non-Biomechanical Strategies for Dance Injury Prevention: A Literature Review

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ABSTRACT

Dancers face a high risk of injury due to the biomechanical and artistic demands of training and performance. This study aims to review the efficacy of *biomechanical* and *non-biomechanical interventions* for injury prevention in dance. A literature search was conducted using Google Scholar with the keywords *"injury prevention" + dance + RCT* , limited to publications from the past five years (2021–2025). From the first 50 search results, and after removing duplicates and screening abstracts and full texts, 43 articles were included in the final analysis. Findings indicate that a wide range of interventions have been explored, with varying levels of evidence for their effectiveness. Biomechanical approaches such as neuromuscular training, strength and conditioning, and balance-focused programs were generally associated with positive outcomes in reducing injury risk and improving movement efficiency. However, their effectiveness often depended on the alignment of the program with dancers' specific training contexts and developmental stages. Non-biomechanical interventions—including education, injury surveillance, workload management, and psychosocial support—were less frequently tested in randomized designs but offered promising complementary benefits, particularly in enhancing injury awareness, promoting safer training behaviors, and fostering a supportive performance environment. Mixed interventions that combined physical training with educational or participatory components showed the most consistent positive outcomes. These results highlight the importance of multidimensional strategies tailored to the unique needs of dance populations.

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INTRODUCTION

In the modern era, societies across the globe are increasingly confronted with complex and multifaceted challenges, particularly in the realm of public health. One of the most pressing issues is the rapid aging of the global population, which has led to a significant rise in the prevalence of cognitive impairment among older adults. For example, recent data indicates that in the past decade, the prevalence of mild cognitive impairment (MCI) among the elderly in China reached 19%, a figure notably higher than that of neighboring Japan during the same period (Shi et al., 2022; Yuan et al., 2022). In parallel, mental health disorders have emerged as a critical concern worldwide. The lifetime prevalence of mental disorders is estimated at 26–33%, contributing to 9% to nearly 17% of the total global disease burden (Yan et al., 2024). Individuals affected by mental illness often face severe consequences, including a reduced life expectancy of 10–15 years, a two- to threefold increase in the risk of developing chronic diseases, and a substantially diminished quality of life. These statistics underscore the urgent need for integrated, preventive, and rehabilitative approaches to address the growing mental and cognitive health crisis on a global scale.

Dance has emerged as a promising intervention to address the growing cognitive and mental health challenges associated with modern life. For older adults with mild cognitive impairment (MCI), dance activities have been shown to significantly enhance global cognition, memory,

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visuospatial function, cognitive flexibility, attention, and balance (Yuan et al., 2022). Beyond cognitive benefits, dance also offers psychological and developmental advantages across the lifespan. Prenatal dance interventions, for example, have been linked to more advanced cognitive and motor development in children, both as infants and toddlers, indicating its potential in early life health promotion (Perjes et al., 2022). Compared to other physical activities, dance has demonstrated superior effects in improving motivation, social cognition, and memory, while also reducing psychological distress (Yan et al., 2024). For senior women, dance serves not only as a means to preserve physical function but also as a pathway to maintaining independence and enhancing life satisfaction (Zygmont et al., 2023). Moreover, the integration of online dance activities has shown significant promise in improving the subjective well-being of the elderly by fulfilling basic psychological needs and strengthening perceived social support (Jiangyuan and Kim, 2023). Collectively, these findings highlight dance as a holistic, accessible, and multifaceted approach to supporting cognitive, emotional, and social well-being across various stages of life.

Despite its numerous physical and cognitive benefits, dance carries a significant risk of injury, particularly among pre-professional and professional dancers. Overuse and chronic injuries—especially in the lower extremities—are the most frequently reported, affecting both students and teachers across various dance genres (Critchley et al., 2021; Dang et al., 2022). Injury incidence varies widely, with estimates ranging from 0.8 to 4.7 injuries per 1,000 dance hours, and many of these injuries are linked to repetitive movement, fatigue, and overtraining. Large-scale data from The Royal Ballet revealed that over five years, dancers experienced 1,332 medical-attention injuries and 427 time-loss injuries, with overuse injuries more prevalent among soloists and those with a prior history of injuries (Shaw et al., 2021). The risk was further influenced by age, with older dancers more susceptible to both traumatic and medical-attention injuries.

Modern and contemporary dancers also show a high injury prevalence—estimated at 82%—with a significant portion involving the ankle, foot, and lower limbs, often affecting joints, ligaments, muscles, and tendons (Sun & Liu, 2024). Acute injuries such as muscle strains and joint sprains are also common, particularly in dancers training across multiple styles and clocking a median of 6.9 to 7.0 hours per week (George, 2023). Gender disparities are evident as well: female dancers are more likely to suffer severe injuries involving bones and miss more performances, while males are more prone to muscle or tendon injuries and contusions, often incurred during high-impact actions such as jumping or stomping (McBride & Bronner, 2023). Additionally, nearly 75% of dancers in a US-based survey reported having experienced at least one injury that limited their ability to dance, with early starters (before age 12) reporting more injuries and less involvement in other sports, although injury rates did not significantly differ based on cross-training participation (Callahan & Mangum, 2025).

There is increasing recognition of the need for structured and comprehensive injury prevention strategies within the dance community to support both performance and long-term dancer health. Critchley et al. (2021) emphasized that understanding the scope of injury in the studio environment is essential for developing effective preventive measures, especially for the underserved majority of dancers. Specific prevention methods tailored to modern and contemporary dancers appear feasible as more research uncovers detailed risk factors and injury mechanisms (Sun & Liu, 2024). However, many current approaches lack a holistic perspective, particularly in neglecting some components that are vital for overall resilience (Dang et al., 2022). Although the implementation of prevention and rehabilitation strategies is widely recommended for dancers of all ages and skill levels, George (2023) noted that the actual usage and effectiveness of these strategies remain largely undocumented. Recent developments in cross-training and conditioning programs suggest promise in enhancing both performance and injury resistance (Ambegaonkar et al., 2023). Moreover, injury prevention approaches now range widely from physical conditioning and neuromuscular warm-ups to psychological skills training and educational interventions, each with varying durations and adherence levels (Critchley et al., 2025). This diversity indicates a growing shift toward multi-dimensional and dancer-specific preventive frameworks.

Biomechanics plays a crucial role in injury prevention within dance by offering a scientific understanding of human movement, particularly in relation to the mechanical structure and function of the body. As explained by Fotaki et al. (2021), biomechanical analysis provides valuable data on muscular activation and movement characteristics, enabling targeted interventions to reduce injury risk. Since all dance movements inherently adhere to biomechanical principles, any deviation from these principles can lead to both acute and chronic injuries (Li et al., 2022). This is especially evident in the case of complex joint regions such as the hip, where injuries are highly varied and require a comprehensive grasp of dance-specific biomechanics for effective treatment and prevention strategies (Migdou et al., 2024). Therefore, integrating biomechanical assessment into dance training and rehabilitation can significantly enhance injury prevention efforts.

Despite the high physical demands and popularity of various dance genres, current research on injury prevention in dance remains limited and unevenly distributed. Kolokythas et al. (2022) highlight a notable research gap, stating that no injury prevention intervention has been specifically designed for dancers, underscoring a lack of tailored, evidence-based approaches. Furthermore, Thind (2023) points out the minimal research attention given to dance disciplines beyond ballet—such as modern, contemporary, folk, hip-hop, and street-style—despite their widespread global practice. This underrepresentation suggests that the injury burden and associated risk factors in these genres may be underestimated or insufficiently addressed in current literature. In response to these gaps, the present study aims to review the efficacy of both biomechanical and non-biomechanical interventions for injury prevention in dance, thereby providing a more comprehensive understanding to support the health and performance of dancers across disciplines.

METHOD

We conducted a literature search in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) (Moher et al., 2009) using Google Scholar to identify articles in English from 2021 to July 31, 2025. The search terms were ("injury prevention" AND "dance" AND "RCT"). The use of the term RCT (Randomized-Controlled Trial) is intended to ensure the obtained literature is of high quality at the level of RCT-based testing. The results analyzed do not have to be RCT research reports, but also theses, systematic reviews, and meta-analyses, as well as methods other than RCTs, as long as they are explicitly stated. We excluded duplicate articles and articles that did not prioritize injury as the main research theme, as well as articles without abstracts. Number of records identified limited to the first five pages of Google Scholar search results to maintain process efficiency without sacrificing validity, avoid information bias from low-impact or irrelevant articles, and save researcher resources. Several research use this strategy when conducting literature review (Seuntjens et al., 2024; Chatterjee et al., 2021).

The overall literature search results were entered into a single database and screened. Articles meeting the inclusion criteria were summarized by identifying the type of intervention and outcome of the study. Intervention-related topics were further subdivided into topics based on intervention type (biomechanical and non-biomechanical) and further subdivided. Outcome-related topics were further subdivided based on outcome quality.

RESULTS AND DISCCUSION

Literature Search and Included Studies

The PRISMA flowchart (Figure 1) shows a total of 1,210 potential studies identified through Google Scholar. After removing duplicates, articles without abstracts, articles with irrelevant titles, and articles not in English, 40 studies were screened with titles and abstracts, and four studies were excluded. The following is a review of 36 studies focusing on the type of intervention and the quality of outcomes from the intervention.

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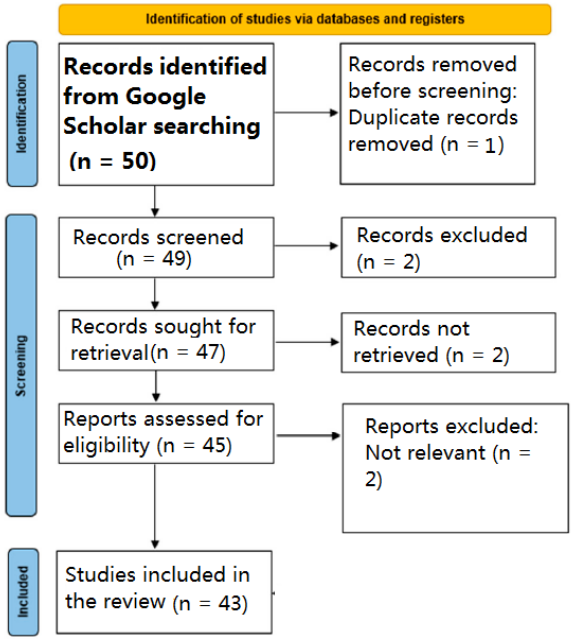

Figure 1. PRISMA flow chart of the studies via Google Scholar search

Characteristics of Interventions in Included Studies

Table 1 summarizes the interventions for injury prevention in dancers and their reported outcomes, while Table 2 categorizes the studies based on research design. A total of 43 studies were reviewed, consisting of nine randomized controlled trials (RCTs), seven non-RCTs (non-randomized, pilot, quasi-experimental), eight survey/observational/qualitative studies, ten systematic reviews/meta-analyses, and six implementation/participatory/mixed studies. Four additional articles with multiple or ambiguous designs were included in the dominant categories.

Table 1. Summary of Injury Prevention Interventions in Dance

Intervention Type	Examples of Interventions	Reported Outcomes
Biomechanical	Neuromuscular training, strength & conditioning, Pilates, targeted warm-up programs	↑ balance, ↑ postural control, ↑ muscle strength, ↓ injury incidence (mixed results)
Non-Biomechanical	Questionnaires, surveillance systems, self-reported experiences, consensus guidelines	↑ awareness of injury patterns, improved validity of tools, highlighted underreporting, calls for consistent monitoring
Mixed	Dance-specific conditioning, coping/education programs, co-created prevention frameworks	↑ function, ↑ engagement, ↓ injury risk factors; evidence sometimes inconclusive

Table 2. Study Designs Represented in the Literature

Study Design	Number of Studies	Key Features
Randomized Controlled Trials (RCT)	9	Tested neuromuscular training, Pilates, dance-specific programs
Non-RCT (pilot, quasi-experimental)	7	Evaluated warm-ups, feasibility, training load

Survey / Observational / Qualitative	8	Questionnaires, surveillance, self-reports
Systematic Review / Meta-Analysis	10	Synthesized interventions across populations
Implementation / Participatory / Mixed	6	Stakeholder engagement, co-designed frameworks
Total	**43**	—

The findings indicate that dancer injury-prevention strategies generally fall into three categories—biomechanical, non-biomechanical, and mixed—with biomechanical interventions being the most common, though implementation and adherence remain key challenges.

Biomechanical interventions

Biomechanical interventions focus on physical, neuromuscular, strength, stability, balance, and body techniques to prevent injury. The literature presents various forms of biomechanical interventions. These include neuromuscular training and conditioning (8 studies), strength/resistance/conditioning/Pilates (5 studies), injury prevention programs (3 studies), balance, postural control, and joint stability (4 studies), and general sport-based biomechanics (3 studies).

Neuromuscular training and conditioning interventions are training approaches aimed at improving coordination, strength, stability, and movement control through integrated stimulation of the nervous and muscular systems to prevent injury and enhance movement performance. Zhang et al. (2021) provide a clear example of this approach through a randomized controlled trial involving 42 elite youth ballroom dancers. Participants in the NMT group underwent a 10-week program consisting of three 60-minute sessions per week, which included ballroom-specific warm-ups, progressive neuromuscular drills, and post-training stretches. The training was carefully designed to align with the technical and physical demands of ballroom dancing. Neuromuscular training programs can be highly specific, such as SIPP (Cofré-Fernández et al., 2021), 11+ Dance (Sudds et al., 2023), and an adaptation of FIFA 11+ for ballet (Kolokythas et al., 2022a). Other studies using neuromuscular training and conditioning include Cofré-Fernández et al. (2021), Kolokythas et al. (2022b), Kaufmann et al. (2023), Shepherd (2022), and Vexler (2020).

Strength and conditioning-based interventions in dance have been implemented through various structured approaches. In a study by Drysdale (2021), an eight-month High Intensity Resistance and Impact Training (HiRIT) program was implemented for elite adolescent ballet dancers, encompassing high-intensity strength training and impact activities aimed at supporting musculoskeletal health. The program was conducted in a dance studio and included lower-body strengthening and spinal training components. Meanwhile, Ngo et al. (2024) in their systematic review identified various types of conditioning exercises used in previous studies, such as resistance training, plyometrics, and vibration training, typically administered weekly and progressively adjusted to the dancer's fitness level. Dang (2024) implemented a 12-week strength and fitness intervention on pre-professional dancers in China, with two weekly sessions of 40–60 minutes each. The intervention included core strengthening, muscular endurance training, and the development of motor control and trunk stability.

The key similarity between strength, resistance, conditioning, and Pilates, which allows them to be grouped into one category, is that they are all physical interventions focused on increasing muscle capacity and active body control through structured exercise. These interventions are designed to strengthen the musculoskeletal system, improving stability, posture, dynamic balance, and neuromuscular endurance, which directly contribute to the body's resilience to the repetitive biomechanical loads of dance. While techniques and

intensities can vary—for example, resistance training uses external loads, conditioning is more general and functional, and Pilates emphasizes core control and alignment—they all share the common goal of increasing movement efficiency, preventing injury from muscle weakness or structural imbalances, and improving the dancer's overall physical performance. Other studies in this category include Patil and Raj (2024) and Che et al. (2025).

Two pieces of literature, namely Gram et al. (2025) and Sadhu and Patra (2025), describe injury prevention programs (IPP) as biomechanical interventions. An Injury Prevention Program (IPP) is a structured and targeted set of physical interventions designed to reduce the risk of injuries by improving physical capacity and correcting biomechanical deficiencies in vulnerable areas of the body. Typically integrated into warm-up routines or regular training sessions, IPPs aim to address specific injury patterns observed in particular sports or dance forms. For example, Gram et al. (2025) implemented an IPP for rhythmic gymnasts, focusing on the knees, lower back, and hip/groin—regions frequently affected by overuse injuries. The program, delivered over eight months, involved exercises intended to enhance strength and flexibility in those areas and was incorporated into athletes' regular warm-up sessions. Meanwhile, Sadhu and Patra (2025) proposed an IPP in the form of a 12-week Intrinsic Foot Strengthening Program (IFSP) for male Bhangra dancers. This intervention aims to improve foot biomechanics and plantar pressure distribution through daily foot-specific exercises, addressing risk factors associated with lower limb injuries. Both examples illustrate how IPPs are customized to the unique physical demands and injury profiles of the target population, with structured duration, frequency, and specific physical targets to support injury risk reduction.

The Balance, Postural Control, and Joint Stability approach in injury prevention focuses on enhancing the neuromuscular coordination and sensorimotor responsiveness required to maintain body equilibrium during both static and dynamic movement. This method aims to reduce the likelihood of injury by improving a dancer's ability to anticipate, adapt to, and recover from biomechanical challenges, such as landing, turning, or shifting weight.

An exemplary application of this approach can be seen in Hansen et al. (2024), who implemented a 12-week online dance training program for older adults consisting of weekly contemporary (improvisational) and salsa dance classes. The contemporary dance sessions incorporate breathing-focused warm-ups and guided improvisation using Laban's choreological principles to encourage movement variation, spatial awareness, and adaptable body control. Participants engaged in tasks such as leaping and landing softly on one leg while maintaining upper-body movement, which directly challenged dynamic balance and joint stability. The use of metaphoric imagery—like landing on a waterlily without disturbing it—further stimulates controlled movement and postural awareness. Salsa classes progressively introduce rhythmical footwork, directional changes, and turns in alignment with music tempo, all performed individually to accommodate the online delivery. Together, these classes foster multi-dimensional training of balance, postural control, and lower-limb joint stability through controlled, varied, and rhythmically structured movement practice. Additionally, other studies such as Fratnik et al. (2025), Guo et al. (2024), and Kishon & Sarig Bahat (2023) explored balance-related interventions through dance-specific assessments, integrated hip-ankle rehabilitation, and strength/aerobic training regimens.

In this classification, general sport-based biomechanics refers to an injury prevention approach that uses general biomechanical principles from exercise science—not those specific to dance—to improve strength, joint stability, motor control, and movement efficiency. Multicomponent Injury Prevention Programs (MIPP) (Jimenez-Garcia et al., 2023) is an example of this approach. MIPP serves as an umbrella framework that combines at least three of the following elements: strength, plyometrics, agility, balance, and flexibility—all of which are key biomechanical components for supporting musculoskeletal integrity and neuromotor

control. Although MIPP was developed primarily for youth athletes, its foundational emphasis on Fundamental Movement Skills (FMS)—such as locomotor actions (running, jumping), balance (static and dynamic), and object control—makes it transferable and adaptable to the needs of dancers. In practice, MIPP-based interventions often include structured neuromuscular training sessions with supervised feedback on movement quality and exercise execution, thereby enhancing both motor competence and injury resilience. This makes general sport-based biomechanics, via MIPP, an effective and scalable approach to dance injury prevention, especially when dance-specific programs are unavailable or when a foundational movement screen is needed to build physical literacy and biomechanical readiness. Other studies that fall into this category are Ambegaonkar et al. (2024) and Wolf et al. (2022).

Non-Biomechanical Interventions

Non-biomechanical interventions focus on monitoring, education, reporting, injury surveillance, training load planning, and psychosocial approaches and tracking systems. Three categories of non-biomechanical interventions were identified in the literature: injury surveillance and monitoring (4 articles), education, perception, psychosocial, and policy (5 articles), and load planning, adaptation, and dancer response (2 articles).

Injury surveillance and monitoring in dance represents a non-biomechanical preventive strategy aimed at regularly tracking and analyzing health-related data to inform injury prevention efforts. Thind (2023) developed an online injury surveillance system for dancers using a Delphi-consensus method and usability testing to ensure that key data elements are standardized and user-friendly, enhancing access to injury epidemiology across dance disciplines. The updated guidelines from the International Association for Dance Medicine and Science (IADMS), as outlined by Kenny et al. (2024), recommend consistent definitions of injury and exposure, context-specific screening tools, and collaborative data reporting protocols to improve the reliability and comparability of injury data. Complementing these structural initiatives, Junge et al. (2022) applied a weekly self-report monitoring system (PAHM) across three professional ballet companies, capturing musculoskeletal complaints, illnesses, and mental health issues in real-time throughout a season. These approaches reflect a shift toward dancer-centered monitoring practices, promoting early detection, workload balance, and informed decision-making to mitigate injury risks and enhance dancer well-being. Another paper in this category is Fuller (2021) which studies injury surveillance in dance training.

The classification of non-biomechanical interventions in dance injury prevention includes a consolidated category encompassing education, perception, psychosocial support, and policy. These four approaches are grouped together because they share a common foundation in behavioral and socio-cultural change rather than targeting neuromuscular or physical mechanisms directly. Each of these elements addresses the broader environment in which dancers operate—shaping their beliefs, behaviors, and access to support systems.

Educationally, there is a clear need for improved injury literacy among both dancers and instructors. For example, adolescent ballet dancers often conceal injuries due to fear of judgment or misunderstanding from instructors, indicating a lack of effective education about safe practices and injury disclosure (Cheers et al., 2023). In terms of perception, dancers' views about injuries, pain, and the dance environment shape their willingness to seek help and adopt preventive strategies. Misconceptions that normalize pain or equate injury with weakness discourage early reporting and care. Psychosocially, support systems—such as empathetic communication with teachers and healthcare professionals—are critical, as fear, stress, and performance pressure have been shown to influence injury management and underreporting. Finally, policy-level interventions emerge through research like George (2023), which emphasizes the importance of systematic injury surveillance and the development of validated

tools such as the PADIP-Q to guide safe participation among young dancers in private studios. Collectively, these approaches underscore that beyond biomechanics, fostering a culture of awareness, emotional safety, and structured monitoring is essential for injury prevention in dance settings. Other studies in this category are Donaldson et al. (2025) about co-design programs and Al Attar et al. (2023) on the awareness of FIFA 11+.

Another category of non-biomechanical interventions is load planning, adaptation, and dancer response. Load planning, adaptation, and dancer response are combined into one category of non-biomechanical interventions because they relate directly to how the dancer's body interacts with training loads and how the body's internal responses to physical stress are managed from a management and physiological perspective, rather than from a movement biomechanics perspective. This category reflects a preventative approach that focuses on regulating the intensity, duration, and frequency of training, and how the dancer's body—both individually and collectively—adapts to these demands.

There are two pieces of literature that fall into this category, namely Fuller (2021) and Kisho and Bahat (2023). Melanie Fuller's (2021) doctoral research illustrates this category by examining injury patterns during transitions in dance training and professional careers. Her work highlights how poorly managed training loads—such as abrupt increases in intensity or spikes leading to performances—were associated with injury clusters, particularly during the initial weeks of tertiary dance programs. Fuller also underscores the importance of artistic staff's role in load planning, revealing a gap between artistic goals and injury prevention strategies. Through both surveillance data and end-user perceptions, her findings advocate for intentional, phased training load progression to allow dancers adequate physiological and psychological adaptation.

Similarly, Kishon and Bahat (2023) explored musculoskeletal injury risks in pre-professional modern dancers before and after the COVID-19 pandemic. Their study found that aerobic fitness and independent strength training practices were associated with lower injury incidence, indicating that the body's adaptive capacity—shaped by overall conditioning and not just technique—plays a crucial role in injury prevention. Their findings point to the need for dance programs to integrate structured cross-training and monitor cumulative training hours to mitigate risk, especially under disrupted conditions like those during the pandemic.

Mixed interventions

Blended interventions integrate physical exercise with educational strategies, interviews, psychosocial surveys, or participatory design. There are two types of blended intervention literature: those using multi-component interventions and those using implementation review methods. The DANCE training protocol developed by Thomsen et al. (2023) represents a multi-component injury prevention intervention that integrates progressive physical training with elements of balance, gait, and muscular conditioning, using salsa dance as its medium. This program is structured around four progressive stages of salsa choreography, each targeting specific fall-related mechanisms such as forward, backward, and lateral movement, as well as weight shifts through twists and turns. The steps are carefully categorized and ranked based on complexity and their ability to challenge postural control by narrowing the base of support. Participants must master each stage before progressing to the next, ensuring individualized adaptation and minimizing injury risk. Sessions include both individual and paired practice, with role alternation between leader and follower to evenly distribute balanced challenges. To address limitations in prior dance-based interventions, each session begins with solo movements that encourage unsupported standing. The DANCE protocol is further reinforced by regular supervision and adherence checks by researchers, ensuring consistency with the designed training objectives. This structured, layered approach allows the program to simultaneously enhance multiple components relevant to injury prevention, such as muscle

strength, coordination, and balance control, making it an exemplary model of a multi-component intervention in dance. Other multi-component approaches in the literature include Dance-Specific Neuromuscular Conditioning and Injury Prevention Training (Long et al., 2021) and I-PROTECT (Ageberg et al., 2025). Literature reviews highlighting these approaches were conducted by Critchley et al. (2024) and Green et al. (2024).

Mixed method implementation reviews were found in four pieces of literature, namely Lutz et al. (2024), Bullock et al., (2024); Benoit-Piau et al. (2023), and Stephenson et al. (2021). Articles in this category review previous literature on implementation. The four literature reviews collectively emphasize that effective injury prevention in dance and sports requires a multidimensional approach that integrates both biomechanical and non-biomechanical strategies. Lutz et al. (2023) highlights neuromuscular training (NMT) as a biomechanical intervention, while also discussing non-biomechanical aspects such as coach support, time management, and participant perception, which influence the implementation of NMT programs. Similarly, Bullock et al. (2024) assess strategies like NMT and protective equipment alongside rule changes, educational initiatives, and policy-level interventions, reflecting a comprehensive scope. Benoit-Piau et al. (2023) examine both physical interventions such as strength and conditioning, and cognitive strategies such as motor imagery, underscoring the interplay between body and mind in injury prevention. Finally, Stephenson et al. (2021) synthesize findings from numerous systematic reviews, covering a broad spectrum of biomechanical (eg, landing techniques, plyometrics) and non-biomechanical (eg, education, policy changes) interventions.

Outcome Qualities of Interventions

The outcomes of each category can be seen in Table 3. The results of the cross-tabular analysis between intervention types and effectiveness levels indicate that injury prevention in dance requires a multi-dimensional approach. Biomechanical interventions based on neuromuscular training and conditioning have been shown to be most consistently effective in reducing injury risk and improving performance, as reflected in the study by Cofré-Fernández and Zhang. However, several other studies, such as Kolokythas et al., have shown varying results, indicating the importance of program quality, training duration, and appropriateness of the implementation context.

Table 3. Intervention Categories Based on Form and Efficacy

Intervention Type	Proven Effectiveness	Limited / Partial Effectiveness	Insignificant / Inconclusive	No Effectiveness Data Yet
Neuromuscular Training & Conditioning	Cofré-Fernández (2021), Zhang (2021)	Sudds et al. (2023), Kaufmann (2023), Shepherd (2022), Vexler (2020)	Kolokythas et al. (2022a, 2022b)	-
Strength / Resistance / Conditioning / Pilates	Dang (2024), Ngo et al. (2024)	Patil & Raj (2024), Li Che et al. (2025)	Drysdale (2021)	-
Injury Prevention Programs (IPP)	-	Sadhu & Patra (2025)	Gram et al. (2025)	-

Balance, Postural Control, Joint Stability	-	Guo et al. (2024), Kishon & Bahat (2023)	Hansen et al. (2024)	Fratnik et al. (2025)
General Sport-based Biomechanics	Jimenez-Garcia et al. (2023)	Ambegaonkar et al. (2024), Wolf et al. (2022)	-	-
Non-Biomechanics: Surveillance & Monitoring	-	-	-	Thind (2023), Fuller (2021), Kenny (2024), Junge (2024)
Non-Biomechanical: Education, Perception, Psychosocial, Policy	-	-	-	Cheers (2023), George (2023), Black (2021), Donaldson (2025), Al Attar (2023)
Non-Biomechanics: Load Planning & Response	-	Kishon & Bahat (2023)	Fuller (2021)	-
Mixed Interventions (Biomechanical + Non-Biomechanical)	Bullock et al. (2024)	Long et al. (2021), Wolf (2022), Benoit-Piau (2023), Ambegaonkar (2024)	Critchley et al. (2024), Green et al. (2024)	Critchley et al. (2023), Thomsen (2023), Stephenson (2021), Lutz (2024), Ågeberg (2025)

DISCUSSION

Our primary objective was to review the efficacy of both biomechanical and non-biomechanical interventions for injury prevention in dance. Emerging evidence suggests that mixed interventions, which integrate physical and non-physical components, hold considerable promise, as illustrated in the studies by Bullock et al. (2024) and Critchley et al. (2024). However, their effectiveness remains inconclusive due to methodological complexities. Taken together, these findings indicate that the most effective approach to injury prevention in dance is likely achieved by combining evidence-based biomechanical interventions with systemic support measures such as monitoring, education, and a holistic, needs-based approach tailored to the dancer.

Non-biomechanical interventions—including injury monitoring, education, psychosocial interventions, and load planning—have not yet demonstrated measurable quantitative results in research, but are qualitatively recognized as important as a systemic foundation for sustainable injury prevention. Studies such as Fuller (2021) and Kishon & Bahat (2023) emphasize the need for awareness and the role of coaches and artistic staff in adaptive load planning. Non-biomechanical interventions could contribute to gaps in biomechanical method effectiveness in the form of mixed interventions.

Biomechanical categories that adopt general sport principles, such as the Multilateral Injury Prevention Program (MIPP), are still conceptual but show promise, especially for young dancers. Meanwhile, generic injury prevention programs like the IPP (e.g., FIFA 11+) have shown inconsistent results in dance populations, suggesting the need for contextual adaptation to the specific needs of the dance world. Further research that tailors these sport-based programs to the biomechanical demands and movement vocabulary of dance is essential. This includes not only modifying exercise content and delivery methods but also ensuring that assessment tools reflect dance-specific risks and performance outcomes. Integrating dance

pedagogy with sport science principles may enhance the relevance, adherence, and effectiveness of such programs in both pre-professional and professional dance settings.
Finally, strength training, resistance training, and Pilates also demonstrated moderate to high effectiveness in reducing musculoskeletal risk factors, especially when performed independently and consistently. Meanwhile, interventions focused on balance, joint stability, and postural control tended to show partial effectiveness, suggesting these approaches are more appropriate as complements to broader prevention programs.
The implications for practice highlight the importance of tailoring injury prevention strategies to the unique biomechanical and artistic demands of dance. While sport-based programs offer a valuable starting point, their effectiveness in dance requires contextual adaptation that aligns with the movement patterns, aesthetics, and training culture of dancers. Dance educators, physiotherapists, and choreographers should collaborate to co-design programs that integrate both physical conditioning and artistic expression, ensuring exercises are functionally relevant and performance-oriented. Regular monitoring, feedback loops, and dancer engagement in program development are essential to foster adherence, reduce injury risk, and support long-term dancer health and performance sustainability.

CONCLUSION

This review underscores the multifaceted nature of injury prevention in dance, spanning biomechanical, non-biomechanical, and multi-component approaches. While biomechanical interventions—such as neuromuscular training, strength conditioning, and postural control—demonstrate high potential in reducing injury risk, their effectiveness increases when complemented by non-biomechanical strategies like education, monitoring, and psychosocial support. Moreover, multi-component programs that integrate both domains tend to offer more comprehensive and context-sensitive solutions. Ultimately, the diversity of methods highlights the need for interdisciplinary collaboration and individualized interventions that are responsive to dancers' physical demands, cognitive engagement, and artistic goals.

DECLARATIONS

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REFERENCES

Ageberg, E., Brodin, E. M., Linnéll, J., Moesch, K., Donaldson, A., Adébo, E., Benjaminse, A., Ekengren, J., Granér, S., Johnson, U., Lucander, K., Myklebust, G., Møller, M., Tranaeus, U., & Bunke, S. (2022). Cocreating injury prevention training for youth team handball: Bridging theory and practice. *BMJ Open Sport & Exercise Medicine*, *8*(2), e001263. https://doi.org/10.1136/bmjsem-2021-001263

Al Attar, W. S. A., Alramadhani, I., Aljabri, M. M., Ghulam, H. S. H., Alyami, M., Alarifi, S., & Sanders, R. H. (2021). 419 The fédération internationale de football association (FIFA) 11+ injury prevention program: Awareness, implementation and opinion of worldwide professional and semi-professional soccer players and coaches. *Poster Presentations*, A159.3-A160. https://doi.org/10.1136/bjsports-2021-IOC.383

Ambegaonkar, J. P., Chong, L., & Joshi, P. (2021). Supplemental Training in Dance. *Physical Medicine and Rehabilitation Clinics of North America*, *32*(1), 117–135. https://doi.org/10.1016/j.pmr.2020.09.006

Benoit-Piau, J., Benoit-Piau, C., Gaudreault, N., & Morin, M. (2023). Effect of Conservative Interventions for Musculoskeletal Disorders in Preprofessional and Professional Dancers:

A Systematic Review. *International Journal of Sports Physical Therapy*, *18*(2). https://doi.org/10.26603/001c.73793

Black, A. M., Meeuwisse, D. W., Eliason, P. H., Hagel, B. E., & Emery, C. A. (2021). Sport participation and injury rates in high school students: A Canadian survey of 2029 adolescents. *Journal of Safety Research*, *78*, 314–321. https://doi.org/10.1016/j.jsr.2021.06.008

Bullock, G. S., Räisänen, A. M., Martin, C., Martin, M., Galarneau, J.-M., Whittaker, J. L., Losciale, J. M., Bizzini, M., Bourne, M. N., Dijkstra, H. P., Dubé, M.-O., Hayden, A., Girdwood, M., Hägglund, M., McLeod, S., Mkumbuzi, N. S., Mosler, A. B., Murphy, M. C., Myklebust, G., … Emery, C. (2025). Prevention strategies for lower extremity injury: A systematic review and meta-analyses for the Female, Woman and Girl Athlete Injury Prevention (FAIR) Consensus. *British Journal of Sports Medicine*, bjsports-2025-109910. https://doi.org/10.1136/bjsports-2025-109910

Callahan, E., & Mangum, L. C. (2025). Exploring Trends between Dance Experience, Athletic Participation, and Injury History. *International Journal of Sports Physical Therapy*, *20*(3). https://doi.org/10.26603/001c.129805

Chatterjee, A., Nardi, C., Oberije, C., & Lambin, P. (2021). Knowledge Graphs for COVID-19: An Exploratory Review of the Current Landscape. *Journal of Personalized Medicine*, *11*(4), 300. https://doi.org/10.3390/jpm11040300

Cheers, N., Matheson, M., Skinner, I., & Wells, C. (2024). Perspectives and Experiences of Dance-Related Injuries: A Qualitative Survey of Adolescent Pre-Professional Ballet Dancers in Australia. *Journal of Dance Medicine & Science*, *28*(2), 90–108. https://doi.org/10.1177/1089313X231224011

Cofré-Fernández, V., Burgos-Estrada, N., Meneses-Hermosilla, V., Ramirez-Campillo, R., Keogh, J. W., & Gajardo-Burgos, R. (2023). Effects of a specific injury prevention neuromuscular training program for young female dancers. A randomized-controlled trial. *Research in Sports Medicine*, *31*(2), 90–100. https://doi.org/10.1080/15438627.2021.1943388

Critchley, M., Kenny, S. J., Ritchie, A., & McKay, C. D. (2022). Injury Rates and Characteristics Associated with Participation in Organized Dance Education: A Systematic Review. *Journal of Dance Medicine & Science*, *26*(2), 87–105. https://doi.org/10.12678/1089-313X.061522b

Critchley, M. L., Rio, E., Friesen, K. B., Räisänen, A. M., Kenny, S. J., & Emery, C. A. (2025). Injury Prevention Strategies in Dance: A Systematic Review. *Journal of Dance Medicine & Science*, 1089313X251314987. https://doi.org/10.1177/1089313X251314987

Dang, Y. (2024). *Dance injury monitoring, strength and conditioning training for decreasing injury incidence for Chinese pre-professional dancers* [PhD]. School of Sport, Faculty of Education, Health and Wellbeing.

Dang, Y., Chen, R., Koutedakis, Y., & Wyon, M. A. (2024). The Efficacy of Physical Fitness Training on Dance Injury: A Systematic Review. *Sportverl Sportschad*, *38*, 129–139.

Drysdale, L. (2021). *Does bone-targeted training reduce bone injury-related time loss to dancing in preprofessional classical ballet dancers? BalletMor: A feasibility study* [PhD]. University of Canberra.

Fotaki, A., Triantafyllou, A., Papagiannis, G., Stasi, S., Georgios, P., Olga, S., Tsolakis, C. K., & Koulouvaris, P. (2021). The science of biomechanics can promote dancers' injury prevention strategies. *Physical Therapy Reviews*, *26*(2), 94–101. https://doi.org/10.1080/10833196.2020.1832707

Fratnik, M. G., Jupp, I., Petsilas, P., Dunleavy, P., Banger, M., McGregor, A., & Abel, R. L. (2025). *Balance in Dance: A Scoping Review*. MedRxiv. https://doi.org/10.1101/2025.06.04.25328967

Fuller, M. (2021). *Injury surveillance and monitoring during transitions in dance training and careers including end-user perceptions towards training load practices* [PhD, Queensland University of Technology]. https://doi.org/10.5204/thesis.eprints.207339

George, A. B. (2023). *Exploring Self-Reported Participation and Injury Trends in Private Studio Dancers: Implications for Injury Prevention Strategies.* [Master Thesis]. University of Calgary.

Gram, M. C. D., Fagerland, M. W., & Bø, K. (2025). Efficacy of a Rhythmic Gymnastics-Specific Injury Prevention Program: An Assessor-Blinded Cluster-Randomized Controlled Trial. *Scandinavian Journal of Medicine & Science in Sports*, *35*(2), e70022. https://doi.org/10.1111/sms.70022

Green, K. L., Yang, Y., Abaraogu, U., Eastaugh, C. H., Beyer, F. R., Norman, G., & Todd, C. (2024). Effectiveness of dance interventions for falls prevention in older adults: Systematic review and meta-analysis. *Age and Ageing*, *53*(5), afae104. https://doi.org/10.1093/ageing/afae104

Guo, Z., Dong, M., Kim, Y., & Tang, T. (2025). Effects of standard rehabilitation versus integrated hip training on proprioception, and dynamic postural control in sport dancer with ankle sprain. *Isokinetics and Exercise Science*, 09593020251332899. https://doi.org/10.1177/09593020251332899

Hansen, R. K., Jochum, E., Egholm, D., Villumsen, M., & Hirata, R. P. (2024). Moving together—benefits of a 12-week online dance training intervention on static and dynamic postural stability and gait speed in older women: An exploratory pre-post study. *Frontiers in Sports and Active Living*, *6*, 1384387. https://doi.org/10.3389/fspor.2024.1384387

Jimenez-Garcia, J. A., Miller, M. B., & DeMont, R. G. (2023). Effects of Multicomponent Injury Prevention Programs on Children and Adolescents' Fundamental Movement Skills: A Systematic Review With Meta-Analyses. *American Journal of Health Promotion*, *37*(5), 705–719. https://doi.org/10.1177/08901171221146434

Junge, A., Hauschild, A., Stubbe, J. H., & Van Rijn, R. M. (2024). Health Problems of Professional Ballet Dancers: An Analysis of 1627 Weekly Self-Reports on Injuries, Illnesses and Mental Health Problems During One Season. *Sports Medicine - Open*, *10*(1), 79. https://doi.org/10.1186/s40798-024-00753-1

Kaufmann, J.-E., Nelissen, R. G. H. H., Stubbe, J. H., & Gademan, M. G. J. (2022). Neuromuscular Warm-Up is Associated with Fewer Overuse Injuries in Ballet Dancers Compared to Traditional Ballet-Specific Warm-Up. *Journal of Dance Medicine & Science*, *26*(4), 244–254. https://doi.org/10.12678/1089-313X.121522e

Kenny, S. J., Stubbe, J. H., Swain, C. T. V., Honrado, J., Hiller, C. E., Welsh, T. M., & Liederbach, M. J. (2024). An Update on the Six Recommendations from the 2012 IADMS Standard Measures Initiative: Assessing and Reporting Dancer Capacities, Risk Factors, and Injuries. *Journal of Dance Medicine & Science*, 1089313X241288998. https://doi.org/10.1177/1089313X241288998

Kishon, L., & Sarig Bahat, H. (2023). Factors Associated with Musculoskeletal Injuries in Pre-Professional Modern Dancers before and after the COVID-19 Pandemic. *Applied Sciences*, *13*(5), 3018. https://doi.org/10.3390/app13053018

Kolokythas, N., Metsios, G. S., Galloway, S. M., Allen, N., & Wyon, M. A. (2022a). 11+ Dance: A Neuromuscular Injury Prevention Exercise Program for Dancers. *Strength & Conditioning Journal*, *44*(5), 1–9. https://doi.org/10.1519/SSC.0000000000000692

Kolokythas, N., Metsios, G. S., Galloway, S. M., Allen, N., & Wyon, M. A. (2022b). Neuromuscular Training in Pre-Professional Ballet Dancers: A Feasibility Randomized Controlled Trial. *Journal of Dance Medicine & Science*, *26*(3), 181–190. https://doi.org/10.12678/1089-313X.091522e

Kolokythas, N., Metsios, G. S., Galloway, S. M., Allen, N., & Wyon, M. A. (2024). The Effects of 11+ Dance on Physiological Parameters in Adolescent Ballet Dancers: A Randomized Controlled Equivalence Trial. *Journal of Dance Medicine & Science*, 1089313X241300567. https://doi.org/10.1177/1089313X241300567

Li, F., Adrien, N., & He, Y. (2022). Biomechanical Risks Associated with Foot and Ankle Injuries in Ballet Dancers: A Systematic Review. *International Journal of Environmental Research and Public Health*, *19*(8), 4916. https://doi.org/10.3390/ijerph19084916

Long, K. L., Milidonis, M. K., Wildermuth, V. L., Kruse, A. N., & Parham, U. T. (2021). The Impact of Dance-Specific Neuromuscular Conditioning and Injury Prevention Training on Motor Control, Stability, Balance, Function and Injury in Professional Ballet Dancers: A Mixed-Methods Quasi-Experimental Study. *International Journal of Sports Physical Therapy*, *16*(2). https://doi.org/10.26603/001c.21150

Lutz, D., Van Den Berg, C., Räisänen, A. M., Shill, I. J., Kim, J., Vaandering, K., Hayden, A., Pasanen, K., Schneider, K. J., Emery, C. A., & Owoeye, O. B. A. (2024). Best practices for the dissemination and implementation of neuromuscular training injury prevention warm-ups in youth team sport: A systematic review. *British Journal of Sports Medicine*, *58*(11), 615–625. https://doi.org/10.1136/bjsports-2023-106906

McBride, C., & Bronner, S. (2022). Injury characteristics in professional modern dancers: A 15-year analysis of work-related injury rates and patterns. *Journal of Sports Sciences*, *40*(7), 821–837. https://doi.org/10.1080/02640414.2021.2021030

Migdou, A., Triantafyllou, A., Gkrilias, P., Kyriakidou, M., & Papagiannis, G. (2025). Hip Injuries in Dancer Athletes Due to Biomechanical Loading: A Systematic Review. *IOCBE 2024*, 5. https://doi.org/10.3390/engproc2024081005

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & for the PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ*, *339*(jul21 1), b2535–b2535. https://doi.org/10.1136/bmj.b2535

Ngo, J. K., Lu, J., Cloak, R., Wong, D. P., Devonport, T., & Wyon, M. A. (2024). Strength and conditioning in dance: A systematic review and meta-analysis. *European Journal of Sport Science*, *24*(6), 637–652. https://doi.org/10.1002/ejsc.12111

Pan, J., & Kim, K.-H. (2023). A Study on the Factors Influencing the Impact of Online Dance Activity on the Subjective Well-Being of the Chinese Elderly. *The Journal of China Area Studies*, *10*(4), 249–280. https://doi.org/10.34243/JCAS.10.4.249

Perjés, B. B., Mátrai, G., Nagy, B., Erdei, D., Makai, A., Prémusz, V., Kovács, K. A., & Bódis, J. (2022). Prenatal dance activity enhances foetal and postnatal cognitive and motor development. *Physiology International*. https://doi.org/10.1556/2060.2022.00121

Rahman, P., & Mehnaz, S. (2024). International Journal for Multidisciplinary Research (IJFMR). *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.5054029

Sadhu, S., & Patra, R. C. (2025). Efficacy of Comprehensive Foot Strengthening Program on Foot Biomechanics and Plantar Pressure to Reduce Lower Limb Injury Risk in Male Bhangra Dancers: A Randomized Controlled Trial Protocol. *Journal of Dance Medicine & Science*, 1089313X251320734. https://doi.org/10.1177/1089313X251320734

Seuntjens, M. T., Thomassen, T. M. J. A., Van Der Weijden, F. (G. A.), & Slot, D. E. (2025). Plaque scores after 1 or 2 minutes of toothbrushing A systematic review and meta-analysis. *International Journal of Dental Hygiene*, idh.12840. https://doi.org/10.1111/idh.12840

Shaw, J. W., Mattiussi, A. M., Brown, D. D., Williams, S., Kelly, S., Springham, M., Pedlar, C. R., & Tallent, J. (2021). Dance Exposure, Individual Characteristics, and Injury Risk over Five Seasons in a Professional Ballet Company. *Medicine & Science in Sports & Exercise*, *53*(11), 2290–2297. https://doi.org/10.1249/MSS.0000000000002725

Shepherd, M. (2022). *Identifying the Effectiveness of an Online Dance-Specific Protocol on Alignment and Muscle Activation in University Dance Majors* [Master Thesis]. East Carolina University.

Shi, L., Yao, S., & Wang, W. (2022). Prevalence and distribution trends of mild cognitive impairment among Chinese older adults: A meta-analysis. *Chinese General Practice*, *25*(1), 109.

Stephenson, S. D., Kocan, J. W., Vinod, A. V., Kluczynski, M. A., & Bisson, L. J. (2021). A Comprehensive Summary of Systematic Reviews on Sports Injury Prevention Strategies. *Orthopaedic Journal of Sports Medicine*, *9*(10), 23259671211035776. https://doi.org/10.1177/23259671211035776

Sudds, K. J., Maurus, P., Nigg, S. R., Wyon, M. A., & Kolokythas, N. (2023). The Effects of the 11+ Dance Neuromuscular Program on Jump Height and Lower Extremity Biomechanics in

Female Adolescent Dancers: A Non-Randomized Controlled Pilot Trial. *Journal of Dance Medicine & Science*, *27*(3), 139–152. https://doi.org/10.1177/1089313X231178096

Sun, Y., & Liu, H. (2024). Prevalence and risk factors of musculoskeletal injuries in modern and contemporary dancers: A systematic review and meta-analysis. *Frontiers in Public Health*, *12*, 1325536. https://doi.org/10.3389/fpubh.2024.1325536

Thind, A. S. (2023). *Injury Surveillance Systems in Dance; a Critical Review and Systematic Development of an Online System* [Master Thesis]. Macquarie University.

Thomsen, M. J., Liston, M., Christensen, M. G., Vestergaard, P., & Hirata, R. P. (2022). Dancing Against falls iN Community-dwElling older adults (DANCE): A study protocol of a stratified, block-randomised trial. *Injury Prevention*, *28*(1), 93–101. https://doi.org/10.1136/injuryprev-2021-044224

Vexler, Y. A. (2023). Method over matter: A study of break dance headstand practice. *Research in Dance Education*, *24*(2), 138–153. https://doi.org/10.1080/14647893.2020.1816950

Wolf, A., Taylor, A., Wilhelm, J., & Fogarty, K. (2022). *Stabilization Training Compared to Strength Training in Preventing Lower Extremity Injuries* [PhD]. School of Behavioral and Applied Sciences.

Yan, A. F., Nicholson, L. L., Ward, R. E., Hiller, C. E., Dovey, K., Parker, H. M., Low, L.-F., Moyle, G., & Chan, C. (2024). The Effectiveness of Dance Interventions on Psychological and Cognitive Health Outcomes Compared with Other Forms of Physical Activity: A Systematic Review with Meta-analysis. *Sports Medicine*, *54*(5), 1179–1205. https://doi.org/10.1007/s40279-023-01990-2

Yuan, Y., Li, X., & Liu, W. (2022). Dance activity interventions targeting cognitive functioning in older adults with mild cognitive impairment: A meta-analysis. *Frontiers in Psychology*, *13*, 966675. https://doi.org/10.3389/fpsyg.2022.966675

Zhang, M., Ma, H., Liu, Z., Smith, D. M., & Wang, X. (2021). The Effects of a 10-Week Neuromuscular Training on Postural Control in Elite Youth Competitive Ballroom Dancers: A Randomized Controlled Trial. *Frontiers in Physiology*, *12*, 636209. https://doi.org/10.3389/fphys.2021.636209

Zygmont, A., Doliński, W., Zawadzka, D., & Pezdek, K. (2023). Uplifted by Dancing Community: From Physical Activity to Well-Being. *International Journal of Environmental Research and Public Health*, *20*(4), 3535. https://doi.org/10.3390/ijerph20043535