EFFECT OF NINE SQUARE EXERCISE ON FUNCTIONAL ABILITY AND COGNITIVE FUNCTION IN ADULTS WITH INTELLECTUAL DISABILITY

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ABSTRACT

This study aimed to examine the effects of Nine square exercise (NSE) using an Illuminated Nine-Square Dance Pad (INSP) on functional ability and cognitive function in adults with intellectual disability (ID). A randomized controlled trial with assessor blinding was conducted at Rajanukul Institute, Bangkok, Thailand. Forty-six adults with mild to moderate ID were randomly assigned to an experimental group (n = 23) or a control group (n = 23). Both groups participated in 60-minute training sessions, twice a week, for 4 weeks. Functional ability was assessed using the 10-Meter Walk Test (10MWT), Timed Up and Go Test (TUG), Five Times Sit-to-Stand Test (FTSST) and Six-Minute Walk Test (6MWT). Cognitive function was assessed using Simple Reaction Time (SRT), Choice Reaction Time (CRT) and Trail Making Test Part A (TMT-A). After 4 weeks of training, the experimental group showed significant improvement in all functional outcomes and in SRT, SRT accuracy, CRT, CRT accuracy, and TMT-A, while the control group improved only in FTSST, 6MWT, SRT accuracy, and CRT accuracy. Between-group comparisons showed greater improvement in 10MWT, TUG, and SRT in the experimental group. The findings suggest that this program may improve functional ability and cognitive function in adults with ID.

Keywords: Intellectual Disability, Nine Square Exercise, Functional Ability, Cognitive Function, Rehabilitation

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ABBREVIATIONS AND SYMBOLS

10MWT	10-Meter Walk Test
6MWT	Six-Minute Walk Test
ANCOVA	Analysis of Covariance
BDNF	Brain-Derived Neurotrophic Factor
BMI	Body Mass Index
BPM	Beats Per Minute
CPE	Conventional Physical Therapy Exercise
CRT	Choice Reaction Time
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
EEG	Electroencephalography
FTSST	Five Times Sit-to-Stand Test
ICC	Intraclass Correlation Coefficient
ICD-10	International Classification of Diseases, 10th Revision
ID	Intellectual Disability
INSP	Illuminated Nine-Square Dance Pad
IQ	Intelligence Quotient
NSE	Nine Square Exercise
PT	Physical Therapy
RCT	Randomized Controlled Trial
SRT	Simple Reaction Time
TMT-A	Trail Making Test Part A
TUG	Timed Up and Go Test

CHAPTER 1

INTRODUCTION

This research has the major aim to explore the benefit of Nine Square Exercise (NSE) in improving functional ability and cognitive function among adults with intellectual disabilities (ID). By integrating physical activity with cognitive stimulation, offering a comprehensive approach to address the unique challenges faced by adults with ID. The contents in chapter 1 are divided into 7 parts. Details of each part are described below;

1.1 Rationale and Background

Approximately 1-3% of the global population has an intellectual disability (ID) (Maulik et al., 2011; McKenzie et al., 2016). Individual with Intellectual disability is a neurodevelopmental disorder characterized by significant limitations in intellectual functioning and adaptive behavior (Patel et al., 2020; Schalock et al., 2021), often leading to challenges in performing daily activities independently (Boat et al., 2015; Patel et al., 2020). Motor impairments in individuals with ID include reduced muscle strength, balance deficits, and slower reaction times, which contribute to an increased risk of falls and a sedentary lifestyle (Hartman et al., 2010; Vuijk et al., 2010). These physical limitations are further exacerbated by environmental factors such as lack of structured physical activity programs, reduced motivation, and social barriers to participation in exercise (Asonitou et al., 2018; DiPasquale & Kelberman, 2020).

Current studies showed that individuals with ID have lower levels of functional ability compared to their typically developing peers, increasing their vulnerability to obesity, cardiovascular diseases, and early onset of age-related conditions (Jacinto et al., 2024; Oviedo et al., 2014). Although many individuals with intellectual disabilities receive rehabilitation or skills training during childhood, most continue to face difficulties in performing daily activities and acquiring new skills. Research conducted between 2010 and 2023 has found that many individuals with ID, particularly during the postsecondary phase, continue to require substantial support and are unable to live independently. These continuing challenges may be linked to the reduced intensity and continuity of rehabilitation programs, often limited by time, resources, and staffing (Anderson et al., 2024; Sechoaro et al., 2014; Vetri et al., 2021). Consequently, it is important to explore for an effective rehabilitation strategy to functional and cognitive ability promote of these patients. The current rehabilitation strategies emphasize on combines aerobic exercise or dancing with music has been found to be feasible and safe for adults with intellectual disabilities, demonstrating positive changes across all measured ability dimensions without any adverse effects. (Martínez-Aldao et al., 2019; Steyn et al., 2024).

Previous research demonstrated that structured aerobic exercise, dance-based programs, and exergaming significantly improved functional ability parameters in individuals with intellectual disabilities, which are crucial for maintaining independence and reducing the risk of falls and injuries (Jacinto et al., 2024; Perrot et al., 2021; Steyn et al., 2024). Additionally, studies indicated that music-integrated exercise interventions enhance adherence rates and reduced perceived exertion, making them more enjoyable and effective for this population (Chen et al., 2022; Danso et al., 2025). In addition for physical health benefits, exercise was shown to improve cognitive function in individuals with ID by stimulating neurogenesis, enhancing synaptic plasticity, and promoting the release of neurotrophic factors, all contributing to improved cognitive processing, executive function, and memory retention (Moriarty et al., 2019; Pastula et al., 2012).

Nine Square Exercise (NSE) is a structured, multi-directional stepping exercise with music, combining aerobic training with cognitive engagement (Phanpheng et al., 2024; Thanasootr et al., 2022). Previous studies have demonstrated that NSE improves postural stability, neuromuscular coordination, and cognitive function in older adults and individuals with balance impairments (Atipas et al., 2019; Phanpheng et al., 2024; Wannapong et al., 2021). NSE has also been integrated with rhythm-based training to enhance reaction time, cognitive flexibility, and working memory in populations at risk of cognitive decline (Phanpheng et al., 2024; Wannapong et al., 2021). Despite these promising findings, limited research has examined the effects of NSE in individuals with intellectual disabilities. Therefore, the researchers hypothesized that the NSE would not only improve functional ability relating to functional ability but also improve cognitive outcomes for these individuals.

However, research examining exercise interventions in these individuals has not definitively established the optimal duration required to enhance functional and cognitive outcomes, including attention, executive function, and processing speed (Affes et al., 2021, 2023a). Furthermore, utilizing the Nine Square Exercise (NSE) with the current pad may pose challenges for individuals with intellectual disabilities (ID), as many of them often experience cognitive limitations.

Therefore, this study aimed to identify an appropriate illuminated nine-square dance pad (INSP) and subsequently investigated the effects of INSP on variables related to the walking ability of these participants.

1.2 Research Questions

Did a 4-week exercise training program on the INSP and conventional treatment enhance functional ability and cognitive function among adults with ID, and were there significant differences in the outcomes of training on the INSP compared to conventional treatment?

1.3 Objectives of the Study

To compare the effects of a 4-week INSP exercise program and conventional treatment on functional ability and cognitive function in adults with ID and to identify significant differences in outcomes between the two programs.

1.4 Hypotheses of the Study

A 4-week exercise training program on INSP will lead to significant difference in functional ability and cognitive function among adults with ID, with notable differences in training outcomes compared to conventional treatment.

1.5 Scope of the Study

The study employed a Randomized Controlled Trial (RCT) design with assessor blinding at Rajanukul Institute, Bangkok, Thailand. Participants were adults with intellectual disabilities (ID) aged 18 years or older. This study focused on comparing the effectiveness of a 4-week exercise training program between the illuminated nine-square dance pad (INSP) and Conventional Physical Therapy Exercise (CPE) in improving functional ability and cognitive function among adults with ID. Assessments were conducted at two time points: baseline and after 4 weeks of training. The study aimed to compare the 4-week effects of INSP training and Conventional Physical Therapy on functional fitness and cognitive performance in adults with ID.

1.6 Terminologies Used in the Study

1.6.1 Intellectual disabilities (ID): A neurodevelopmental disorder characterized by significant limitations in both intellectual functioning (e.g., reasoning, problem-solving) and adaptive behavior (e.g., social and practical skills). These limitations originate before the age of 18, leading to impairments in daily functioning and the ability to live independently (Patel et al., 2020; Schalock et al., 2021).

1.6.2 Functional ability: An individual's ability can perform activities of daily living effectively and safely, encompassing physical components such as muscular strength, cardiovascular fitness, balance, and mobility, all of which are essential for independent functioning. (Jacinto et al., 2024; Steyn et al., 2024).

1.6.3 Cognitive function: The cognitive processes involved in acquiring, processing, and utilizing information, which include attention, memory, executive function, decision-making, and processing speed (Hartman et al., 2010; Harvey, 2019; Moriarty et al., 2019).

1.6.4 Nine Square Exercise (NSE): A structured, multi-directional stepping exercise conducted within a 3x3 grid, designed to enhance postural control, neuromuscular coordination, and cognitive engagement. This exercise integrates aerobic training with rhythmic and cognitive stimuli, rendering it suitable for populations experiencing balance or cognitive impairments (Atipas et al., 2019; Phanpheng et al., 2024).

1.7 Advantages of the Study

This research investigated the effects of Nine Square Exercise (NSE) on functional ability and cognitive function in adults with intellectual disabilities. By integrating physical activity with cognitive stimulation, the study introduced an innovative exercise approach using the illuminated nine-square dance pad (INSP), which enhanced motor coordination, balance, and cognitive engagement. Enhancing functional ability and cognitive function could lead to greater independence, reduced fall risk, and improved overall well-being in adults with ID. This study could provide insights into how exercise could increase social participation, reduce dependence on caregivers, and enhance self-confidence in this population. This study focused on the effects of a 4-week exercise program, allowing for a comprehensive understanding of its short-term benefits on functional ability and cognitive function outcomes. Findings from this research could contribute to the development of evidence-based exercise guidelines for individuals with ID, potentially improving their quality of life, independence, and social participation.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews literatures related to this study. Details in the chapter were divided into 4 parts including (1) information in intellectual disabilities (ID), (2) current rehabilitation strategy in intellectual disability, (3) nine square dance and (4) outcome assessments of functional ability and cognitive function. Details of each topic are described below;

2.1 Intellectual Disability (ID)

2.1.1 Definition, etiology, and prevalence of intellectual disability

Intellectual Disability (ID), who have limitations in both intellectual functioning and adaptive behavior, is caused by multifactorial and complex factors, potentially involving genetic influences or severe brain injury, while mild intellectual disability is often associated with risk factors such as nutritional deficiencies or exposure to environmental toxins (Katz & Lazcano-Ponce, 2008; Patel et al., 2020). Moreover, complications during pregnancy and prematurity are significant risk factors impacting the etiology of intellectual disability in children. They exhibit below-average intellectual functioning, typically defined by an IQ of less than 70, alongside deficits in conceptual, social, and practical adaptive skills. These challenges, arising before the age of 18 or 22, involve significant difficulties in performing daily activities and participating independently in societal interactions (Boat et al., 2015; Schalock et al., 2021; Shree & Shukla, 2016).

Approximately 1-3% of new cases of intellectual disability (ID) occurred each year worldwide. However, this rate varies across regions and population groups. Reported the prevalence of intellectual disability in Taiwan found a steady increase in the prevalence. A study in India revealed that intellectual disability prevalence varies between rural and urban areas, with higher rates observed in rural populations (McKenzie et al., 2016). According to epidemiological data, males are more likely than females to have ID, with a male-to-female ratio of roughly 1.5:1, especially in low- and middle-income countries (Boat et al., 2015; Buckley et al., 2020; Uzun Cıcek et al., 2020).

Although many individuals with intellectual disabilities receive rehabilitation or skills training during childhood, a substantial proportion continue to experience significant challenges in performing daily living activities and acquiring new skills effectively (Anderson et al., 2024; Sechoaro et al., 2014). Research from 2010 to 2023 have indicated that, despite participating in training or rehabilitation programs, most individuals with intellectual disabilities continue to struggle with daily routines and learning effectively, particularly during the postsecondary phase (Anderson et al., 2024). Many still require substantial support and lack the ability to live independently (Sechoaro et al., 2014). This may be attributed to the reduced intensity and continuity of rehabilitation programs, which are often constrained by limited time, resources and staffing (Anderson et al., 2024; Sechoaro et al., 2014; Vetri et al., 2021), may further affect the optimal functional and cognitive ability Consequently, it is important to explore effective rehabilitation strategies to promote functional and cognitive abilities in these patients.

2.1.2 Diagnostic criteria and severity of intellectual disability

The diagnosis of intellectual disability requires the presence of significant deficits in both intellectual functioning and adaptive behavior (Boat et al., 2015; Patel et al., 2020; Schalock et al., 2021), these limitations must manifest during the developmental period, typically before the age of 18 (Boat et al., 2015; Patel et al., 2018), depending on the diagnostic criteria, reflecting evolving understanding of brain development (Patel et al., 2020; Schalock et al., 2021). Intellectual functioning deficits encompass reasoning, problem-solving, planning, and learning, while adaptive behavior deficits include conceptual, social, and practical skills (Katz & Lazcano-Ponce, 2008). Intellectual functioning is commonly measured using individually administered, norm-referenced IQ tests, with scores two standard deviations below the mean (approximately ≤70) indicating significant impairment (Patel et al., 2020; Schalock et al., 2021). Adaptive behavior deficits, which affect conceptual (e.g., language and problem-solving), social (e.g., interpersonal skills), and practical (e.g., self-care and money management) domains, are assessed through standardized evaluations and clinical observations (Patel et al., 2018; Shree & Shukla, 2016). The diagnosis is based on individually administered standardized assessments, such as the Wechsler Intelligence Scale and the Stanford-Binet Intelligence Scale, along with clinical judgment (Boat et al., 2015; Patel et al., 2018). Key factors include prenatal, perinatal, and postnatal clinical history, physical examination focusing on congenital abnormalities, genetic testing to identify specific biological causes, individual's cultural and linguistic background (Katz & Lazcano-Ponce, 2008; Patel et al., 2018). Intellectual disability is classified into four levels of severity: mild, moderate, severe, and profound (Katz & Lazcano-Ponce, 2008; Patel et al., 2018, 2020; Shree & Shukla, 2016). These levels are based on the extent of intellectual and adaptive impairments, as well as the intensity of support required for daily living and social participation (Patel et al., 2018). This comprehensive diagnostic approach not only identifies the limitations of individuals but also serves as a foundation for creating personalized support plans aimed at enhancing their quality of life and independence (Boat et al., 2015; Patel et al., 2018; Schalock et al., 2021).

2.1.3 Consequences of intellectual disability

Intellectual disability is a neurodevelopmental disorder characterized by significant deficits in intellectual functioning and adaptive behavior. Beyond cognitive impairments, individuals with ID experience neurological abnormalities affecting motor control and cognitive function (Hartman et al., 2010; Vuijk et al., 2010). These deficits stem from structural and functional differences in brain regions responsible for motor learning, working memory, and executive control, particularly in the frontal lobe, motor cortex, and cerebellum (Hartman et al., 2010; Muñoz-Ruata et al., 2013).

Individuals with ID exhibit poor motor coordination, reduced muscle strength, and balance impairments due to dysfunctions in the prefrontal cortex and cerebellum (Hartman et al., 2010). Some evidence indicates lower locomotor and fine motor skills, negatively impacting daily activities (Korkusuz & Top, 2023). These motor difficulties include poor coordination, slower reaction times, reduced gait speed, and impaired perceptual-motor integration, largely caused by central nervous system dysfunction (Hale et al., 2009; Mitic et al., 2021; Oppewal et al., 2018).

Cognitive deficits in ID include executive dysfunction, attention deficits, and slower processing speeds, primarily linked to prefrontal cortex impairments (Muñoz-

Ruata et al., 2013). The cerebellum hypothesis suggests a shared neural mechanism between motor and cognitive functions, reinforcing the interplay between these two domains (Diamond, 2000; Hartman et al., 2010). Individuals with ID often exhibit reduced neural connectivity and cortical inefficiency, further contributing to difficulties in motor learning, balance, and complex cognitive tasks (Frey & Chow, 2006; Vuijk et al., 2010).

There is a strong correlation between cognitive and motor performance in individuals with ID. Studies indicate that individuals with ID struggle with dual-task scenarios where increased cognitive demands negatively impact walking and coordination (Hartman et al., 2010). Additionally, adults with ID often exhibit reduced hippocampal or temporal lobe volume, limiting executive functions and communication skills, which affects social adaptation and independent living (Wang et al., 2023). These neurological impairments contribute to reduced adaptive behavior and motor performance (Hartman et al., 2010).

The combined impairments in motor and cognitive function significantly affect the functional ability, learning and overall health of individuals with ID (Jacinto et al., 2024; Oviedo et al., 2014). Research consistently shows that individuals with ID have lower functional ability levels and poorer balance than their age-matched peers without disabilities, increasing their risk of falls and injuries (Enkelaar et al., 2012). These limitations often lead to sedentary lifestyles, which contribute to obesity, chronic diseases, and functional disabilities (Asonitou et al., 2018; Jacinto et al., 2024; Oviedo et al., 2014). As early aging begins around age 40 in individuals with ID, these health risks become more pronounced, increasing the likelihood of chronic diseases and dementia, ultimately reducing quality of life and increasing mortality rates (Dairo et al., 2016; Jacinto et al., 2024).

Addressing barriers through tailored, engaging physical activity programs is essential to breaking the cycle of inactivity, improving functional ability, and promoting long-term health outcomes for individuals with ID (Asonitou et al., 2018; Hartman et al., 2010; Jacinto et al., 2024). Future interventions should integrate physical and cognitive exercises to optimize neurodevelopmental outcomes and enhance independence in individuals with ID.

2.2 Current Rehabilitation Strategy in Intellectual Disability

Current rehabilitation program for individuals with ID are increasingly personalized and multidisciplinary, aiming to enhance functional ability, learning, and quality of life. These approaches integrate physical therapy, special education, vocational training, and community-based interventions to tailor programs to the specific needs of each individual (Deshmukh & Harjpal, 2024). Technology-aided interventions have become a significant component, with studies demonstrating their effectiveness in improving functional activities, communication, and adaptive responses, while reducing problem behaviors (Lancioni et al., 2023). For offenders with ID, evidence-based therapeutic frameworks such as cognitive behavior therapy (CBT), dialectical behavior therapy (DBT), and motivational interviewing (MI) are utilized, grounded in trauma-informed principles and guided by models like the risk/need/responsivity (RNR) and good lives model (GLM) (Sakdalan & Mitchell, 2025). In educational contexts, interventions focus on sensomotor integration, cognition, and behavior to enhance cognitive and academic achievements in children with mild ID, emphasizing applied research and tailored activities (Macesic-Petrovic et al., 2022). Despite these comprehensive strategies, challenges remain in ensuring accessibility and applicability across diverse populations, highlighting the need for ongoing research and adaptation to individual needs. However, an easy and convenient way to restore yourself today is through exercise and improving your analytical thinking skills. From the literature review, the researcher concluded as follows:

2.2.1 Exercise of functional ability in intellectual disability

Functional ability refers to the ability to perform daily living activities efficiently and safely (Jacinto et al., 2024; Munn et al., 2023; Steyn et al., 2024). It includes multiple components such as muscular strength, cardiovascular fitness, balance and mobility (Martínez-Aldao et al., 2019; Steyn et al., 2024). Individuals with ID often have lower levels of functional ability due to a sedentary lifestyle, obesity, which can negatively impact their quality of life and ability to perform daily activities independently (Asonitou et al., 2018; Jacinto et al., 2024), lack of motivation, limited access to exercise facilities and a lack of structured physical activity programs

(DiPasquale & Kelberman, 2020; Hutzler & Korsensky, 2010; Munn et al., 2023). Thus, current research had the goal of study that what are the type of aerobic exercise interventions can improve functional ability and overall health outcomes in this population (Jacinto et al., 2024; Jacob et al., 2023; Steyn et al., 2024).

Asonitou et al. (2018) executed a 16-week intervention that emphasized muscle strength, endurance, balance, and flexibility, culminating in substantial enhancements among individuals within the exercise group. This supported the notion that structured and tailored exercise programs are crucial for promoting healthier, more active lifestyles in individuals with intellectual disabilities (Appendix B: Table B1) (Asonitou et al., 2018). According with Jacinto et al. (2024) and Oviedo et al. (2014) conducted a 14–24week aerobic exercise by gymnasium-centered and outdoor training. Those in the gym-oriented group recorded substantial progress in lower limb strength and movement skills, confirmed by tests like the sit-to-stand measure, the timed up-and-go trial, and the six-minute walking evaluation. These findings highlighted the importance of prolonged, well-structured exercise interventions for maximizing health benefits in individuals with ID (Appendix B: Table B1) (Jacinto et al., 2024; Oviedo et al., 2014). Therefore, aerobic exercise has been demonstrated to significantly enhance functional ability and overall health in individuals with intellectual disabilities (ID) over the long term. The effects of exercise are influenced by the specific type of exercise performed, underscoring the importance of selecting appropriate exercise modalities to maximize health benefits (Appendix B: Table B1), its impact on cognitive abilities may require more targeted interventions.

2.2.2 Exercise of cognitive function in intellectual disability

Cognitive training for individuals with intellectual disabilities (ID) showed promising results in enhancing various cognitive functions. Technologies such as computerized programs and virtual reality (VR) played a significant role in these interventions. These programs were designed to improve executive functions, working memory, and problem-solving skills, using interactive and personalized approaches to ensure effectiveness and engagement. A study indicated significant improvements in planning skills among adults with mild ID following a computerized cognitive training program, where participants completed tasks more efficiently, highlighting enhanced problem-solving abilities (Acosta Echavarría et al., 2024). Home-based cognitive retraining programs for children utilized web applications and mobile apps to deliver neurocognitive exercises, fostering cognitive development and independence (Kumar et al., 2024). VR-based training effectively improved working memory and inhibitory control in young adults with intellectual developmental disabilities, leveraging immersive environments, though it showed no significant impact on sustained attention (Trigueiro et al., 2024). Programs incorporating EEG neuro-feedback and sensory feedback mechanisms, such as face detection and heart rate monitoring, provided a comprehensive approach to cognitive development, ensuring personalized interventions (Vogt et al., 2013). Gamification and visual feedback in cognitive retraining programs-maintained engagement and motivation among children with learning disabilities, preventing cognitive overload and enhancing retention (Neha Jadhav et al., 2024).

From the literature review, the researcher found that previous study in moderate-intensity of cycling and treadmill walking, has been indicated to increase positive outcomes on reaction times, executive functions, and decision-making abilities through the elevation of blood flow and oxygen levels in the brain, consequently promoting neurogenesis and synaptic adaptability (Moriarty et al., 2019). Moreover, participating in aerobic exercise has demonstrated the ability to stimulate the production of neurotrophic elements, like Brain-Derived Neurotrophic Factor (BDNF), that bolster memory creation and cognitive strength. According with the study incorporating electroencephalography (EEG) have indicated a fall in frontal electrocortical activity, consequently improving cognitive control and attention processing (Vogt et al., 2013). Moreover, current study indicated that an 8-week regimen of structured physical activity brought about significant gains in cognitive functions for young adults facing mild to moderate intellectual disabilities, particularly in the realms of processing speed and executive functions (Appendix B: Table B3) (Pastula et al., 2012). According with recent study had integrated physical activity with attention training, leading to marked improvements in attention and motor coordination in children diagnosed with mild intellectual disabilities (Appendix B: Table B3) (Korkusuz & Top, 2023). In addition, Wang et al. (2023) demonstrated that involvement in a 12-week badminton program produced gains in executive functioning for adults with mild intellectual disabilities (Appendix B: Table B3) (Wang et al., 2023). Short duration of exercise has shown to provide instant mental benefits, notably in terms of concentration and working memory

(Chang et al., 2012). According to Vogt et al. (2013), adolescents with disabilities showed lower electrocortical activity, which resulted in enhanced reaction times (Appendix B: Table B3) (Vogt et al., 2013). According to Huang et al. (2020), engaging in aerobic exercise for just 30 minutes led to notable enhancements in cognitive abilities among children, especially those facing learning challenges (Appendix B: Table B3) (Huang et al., 2020). The findings of Affes et al. (2021, 2023) documented notable gains in reaction time and working memory across a spectrum of exercise intensities, underscoring the benefits tied to moderate physical activity (Appendix B: Table B3) (Affes et al., 2021, 2023a). In their 2023 analysis, Borji et al. investigated the differences between aerobic and resistance exercises, finding that aerobic exercise offers remarkable cognitive enhancements (Appendix B: Table B3) (Borji et al., 2023). A study by Chang et al. 2012 found that the length, intensity, and kind of exercise greatly affect cognitive benefits, especially showing that moderate-intensity aerobic workouts lead to the greatest advancements (Chang et al., 2012).

Thus, from the literature review highlights the potential for improving cognitive function in individuals with intellectual disabilities through both neurologically specific interventions and aerobic exercise. While studies suggest that aerobic exercise can enhance cognitive function, it is noted that interventions targeting functional ability and cognitive improvements have often required separate treatments and extended durations to be effective. This presents a challenge, as the time available for rehabilitation in this individual is typically limited, necessitating a more integrated and efficient approach to maximize benefits.

Therefore, to motivate individuals to undergo rehabilitation and achieve effective outcomes in a shorter time frame, researchers proposed combining exercises that enhance both functional and cognitive abilities with engaging activities. This integrated approach is expected to improve exercise performance and sustain interest, thereby maximizing rehabilitation benefits efficiently.

2.2.3 Dance-based exercise programs

Dance-based exercise programs have emerged as a versatile and effective form of physical activity which involve multi-planar movements and various directional shifts, providing to enhance lower extremity strength, balance, mobility, and flexibility, in various populations (DiPasquale & Kelberman, 2020; Martínez-Aldao et al., 2019;

Steyn et al., 2024). Recent research highlights their positive impact on specific groups, such as cancer survivors, where a 10-week community-based dance program improved aerobic fitness and social connections, enhancing participants' confidence and perceived well-being (Gooney et al., 2024). Similarly, an 8-week structured dance program for individuals with Parkinson's disease significantly improved quality of life and reduced depressive symptoms, particularly enhancing social engagement and emotional well-being (Chen, 2025). For chronic stroke patients, dance-based exergaming demonstrated improvements in cardiovascular function and functional mobility, transitioning successfully from laboratory to home settings with high adherence and safety (Subramaniam & Ma, 2024). In children and adolescents, dance programs yielded mixed results regarding cognitive improvements, although they were found to be as effective as traditional physical education classes (O'Connor et al., 2024). The integration of technology in dance interventions has emerged as a promising strategy to boost participation and fitness levels across various populations, aligning with public health objectives (Tao et al., 2024).

Additionally, Martínez-Aldao et al. (2019) implemented a 10-week dance and music-based exercise program in individuals with ID, which resulted in significant improvements in cardiovascular endurance and muscular strength (Appendix B: Table B2) (Martínez-Aldao et al., 2019). Moreover, virtual and group-based exercise programs are another promising approach for enhancing functional ability. Munn et al. (2023) evaluated the effects of a 10-week virtual Zumba program on functional outcomes in adults with developmental disabilities. Participants who engaged in both low-tempo and normal-tempo Zumba sessions demonstrated significant improvements in aerobic endurance and balance compared to the control group. These findings suggest that virtual exercise programs can increase accessibility and engagement while improving health outcomes in individuals with ID. However, no significant cognitive benefits were observed, possibly due to the exercise program not being specifically designed to target cognitive function and the cognitive assessment tools used may not have been fully suitable for individuals with ID (Appendix B: Table B2) (Munn et al., 2023).

Multi-component exercise programs that incorporate different modalities, such as walking, dancing, and strength training, have also been found to be effective. Steyn et al. (2024) conducted a six-week intervention combining these elements and reported significant improvements in body mass, aerobic capacity, muscular strength, balance, and flexibility (Appendix B: Table B2) (Steyn et al., 2024). This study reinforces the importance of a holistic approach to exercise in improving multiple aspects of functional ability in individuals with ID (Steyn et al., 2024). While the benefits of dance-based exercise programs are evident, further research is necessary to explore long-term outcomes and refine interventions to maximize their effectiveness for different groups, as well as to enhance accessibility and engagement through technological integration.

2.2.4 Effect of music and rhythm for dance-based exercise programs

Music and rhythm are important for enhancing motivation for physical activity. They positively influence mood and enjoyment, making exercise more engaging and sustainable (Chen et al., 2022; Martínez-Aldao et al., 2019; Munn et al., 2023). Studies have shown that exercise with music improves adherence and participation rates, particularly among individuals with intellectual disabilities (Martínez-Aldao et al., 2019). Music also helps reduce perceived exertion, enabling participants to sustain exercise for longer durations (Chen et al., 2022).

Studies have demonstrated that music therapy effectively improves attention in individuals with intellectual disabilities, leading to better engagement and performance in various activities (Dada et al., 2021). Specifically, music listening has been found to enhance selective attention, sustained attention, and cognitive control, all of which are critical for maintaining focus during physical activities. The rhythmic structure of music provides predictable auditory cues that help individuals with ID synchronize their movements, improving neuromuscular coordination and executive function (Danso et al., 2025). In addition to its impact on attention, music also affects cognitive control and emotional responses during exercise. A study by Chen et al. (2021) found that listening to music during acute aerobic exercise significantly enhanced executive function, particularly inhibitory control and working memory (Chen et al., 2021). Studies indicate that music within the 120–140 BPM range significantly improves inhibitory control and attention when paired with moderate-intensity aerobic exercise (Danso et al., 2025). Music with a tempo of 130–150 BPM has been found to increase dopamine levels and enhance exercise enjoyment, leading to greater adherence and reduced perceived exertion (Chen et al., 2021).

Therefore, music and rhythm are important for enhancing the effectiveness of dance-based exercise programs by boosting motivation, mood, and enjoyment with intellectual disabilities in synchronizing their movements, thereby improving neuromuscular coordination and executive function. Moreover, listening to music during exercise has been linked to improvements in inhibitory control, cognitive flexibility, and working memory, particularly when the music is within the 120–150 BPM range. Overall, the integration of music into dance-based exercise programs offers substantial benefits for motivation, cognitive function, and overall participation in physical activity.

2.3 Nine Square Exercise

Nine Square Exercise (NSE) was identified as a structured, multi-directional stepping exercise aimed at enhancing postural stability, neuromuscular coordination, functional ability, and cognitive function across various populations (Phanpheng et al., 2024; Puttipaibool et al., 2022; Thanasootr et al., 2022). Classified as an aerobic exercise, NSE involved continuous rhythmic movements that elevated heart rate and improved oxygen consumption (Outayanik et al., 2017). Participants engaged in stepping movements within a 3x3 grid, which included forward, backward, lateral, and diagonal steps, transitioning from a wide to a narrow base of support (Atipas et al., 2019; Wannapong et al., 2021). The progressive complexity of NSE allowed individuals to advance from simple to more dynamic patterns, effectively challenging motor control, sensory integration, and cognitive processing, making it suitable for those with balance deficits or functional mobility limitations (Outayanik et al., 2017; Phanpheng et al., 2024). In various studies, NSE demonstrated significant improvements in balance, agility, and lower body strength in older adults, contributing to fall prevention strategies (Appendix B: Table B4) (Outayanik et al., 2017; Wannapong et al., 2021). Patients with balance disorders showed enhanced equilibrium and postural stability after eight weeks of training (Appendix B: Table B4) (Atipas et al., 2019). In older adults with Type 2 Diabetes Mellitus, NSE improved muscle strength and performance on the Timed Up and Go test (Appendix B: Table B4)

(Kraiwong et al., 2021). A randomized controlled trial found significant improvements in dynamic balance among overweight female undergraduate students (Appendix B: Table B4) (Udom et al., 2022). Additionally, a study comparing NSE with treadmill exercise revealed similar benefits in cardiorespiratory endurance and flexibility, with NSE yielding greater improvements in perceived quality of life (Appendix B: Table B4) (Puttipaibool et al., 2022). Research involving Ram Thai dance combined with NSE showed significant enhancements in reaction time and cognitive function in older adults, indicating its potential role in interventions for mild cognitive impairment (Appendix B: Table B4) (Phanpheng et al., 2024).

Despite these findings, research specifically examining NSE's effectiveness for individuals with intellectual disabilities remained limited, highlighting the need for further studies to explore its applicability and optimal implementation strategies for this population.

2.4 Functional Ability and Cognitive Function

2.4.1 Outcomes assessment of functional ability

Functional ability refers to an individual's ability to perform daily activities safely, efficiently, and independently. It encompasses multiple physical components, including muscular strength, endurance, balance, flexibility, and aerobic capacity, which are essential for maintaining mobility and reducing the risk of injury or chronic diseases (Jacinto et al., 2024; Steyn et al., 2024).

1. 10-Meter Walk Test (10MWT)

The 10-Meter Walk Test (10MWT) in individuals with intellectual disabilities varies according to the specific population and testing conditions. The 10MWT is a widely utilized tool for assessing gait speed and mobility, making its reliability critical for clinical and research applications. In adolescents and young adults with Down syndrome, the test exhibited good to excellent reliability, with intra-rater ICC values ranging from 0.76 to 0.9 and inter-rater ICCs exceeding 0.9, indicating high consistency across assessments (Sánchez-González et al., 2023). For adults with mild to moderate intellectual disabilities, the 10MWT demonstrated strong concurrent validity with other gait speed tests, showing a correlation coefficient of 0.94, which confirms its reliability in this population (Goh et al., 2024). Additionally, research involving adolescents with intellectual disabilities highlighted the test's sensitivity to real-life motor complexity, revealing that increased task difficulty resulted in longer completion times (Jouira et al., 2025). The feasibility of the 10MWT was also affirmed in older adults with intellectual disabilities, where it was incorporated into a battery of physical fitness assessments, proving manageable for most participants, except those with profound disabilities or wheelchair users (Hilgenkamp et al., 2013). While the 10MWT is shown to be reliable and feasible across various subgroups within the intellectual disability population, it is essential to consider individual characteristics such as age, severity of disability, and the presence of additional motor or cognitive challenges, as these factors may influence the test's reliability.

2. Timed Up and Go Test (TUG)

The Timed Up and Go Test (TUG) is a tool for assessing functional mobility, balance, and fall risk (Blomqvist et al., 2012; Enkelaar et al., 2013). This test measures the time it takes an individual to stand up from a chair, walk three meters, turn around, return, and sit down, a shorter completion time indicates better functional mobility, is especially suitable for adults with intellectual disabilities due to its simplicity and adaptability (Blomqvist et al., 2012). Research shows that adults with ID often experience slower mobility, reduced balance, and an increased risk of falls compared to their neurotypical peers, making the TUG test highly relevant for evaluating these deficits (Enkelaar et al., 2013). The intraclass correlation coefficient (ICC) for TUG in individuals with ID has been reported as 0.59–0.97 (Blomqvist et al., 2012; Salb et al., 2015). Standard error of measurement (SEM) values has been reported to assess test precision, with variations based on age and ID severity (Salb et al., 2015). The TUG has been found to correlate significantly with other functional mobility assessments, such as the berg balance scale $r = -0.718$, $p < 0.001$ and the Functional Reach Test $r = -0.458$, $p < 0.001$. In addition, TUG is related to gait speed in adults with ID. TUG was correlated with the 10MWT ($r = 0.714$), suggesting that it measures relevant aspects of mobility and balance. The test has been used to assess fall risk in individuals with ID, with longer TUG times associated with higher fall risk (Enkelaar et al., 2013). Standard error of measurement (SEM) values has been reported to assess test precision, with variations based on age and ID severity (Salb et al., 2015). Studies indicate that interventions such as dance-based interventions and exercise programs in individuals with ID can significantly improve TUG performance, demonstrating the test's sensitivity to change (DiPasquale & Kelberman, 2020; Munn et al., 2023; Perrot et al., 2021).

3. Five Times Sit-to-Stand Test (FTSST)

The Five Times Sit-to-Stand Test (FTSST) test measures the time taken for an individual to complete five repetitions of rising from a seated position to a full stand and sitting back down again as quickly as possible while maintaining safety and proper posture (Farias-Valenzuela et al., 2024), reflecting both muscle endurance and functional performance (Farías-Valenzuela et al., 2024; Oppewal & Hilgenkamp, 2020). Participants start in a seated position with their arms crossed over their chest and their feet flat on the floor. They are instructed to stand up and sit down five times as quickly as possible without using their hands for support (Farías-Valenzuela et al., 2024; Hilgenkamp et al., 2010). The reliability of the FTSST in adults with ID has been well-documented. Farias-Valenzuela et al. (2024) found that the FTSST demonstrated significant correlations with other functional capacity tests, such as the timed up and go test (TUG) (ICC = 0.74) and the 4 × 10-meter agility test (ICC = 0.61). These findings highlight the concurrent validity of the FTSST as a measure of dynamic strength and mobility in individuals with ID. Furthermore, the test is inversely correlated with measures of upper body strength, such as handgrip strength (r = -0.48 to -0.64), and lower body power, as assessed by the countermovement jump (CMJ) test (r = -0.53), emphasizing its role in evaluating functional performance comprehensively (Farías-Valenzuela et al., 2024).

4. Six-Minute Walk Test (6MWT)

The 6MWT is test for evaluating submaximal aerobic capacity and functional exercise capacity, a simple and safe method (Guerra-Balic et al., 2015; Nasuti et al., 2013). Participants are instructed to walk as far as possible within 6 minutes along a flat corridor marked at regular intervals, unobstructed a measure of the distance walked over a 6-minute period (Casey et al., 2012; Nasuti et al., 2013) which reflects an individual's ability to perform daily physical tasks and their overall functional mobility in adults with intellectual disabilities (Casey et al., 2012; Guerra-

Balic et al., 2015). Studies have consistently demonstrated the reliability and validity of the 6MWT in this population. Guerra-Balic et al. (2015) reported excellent test-retest reliability with an intraclass correlation coefficient (ICC) of 0.96 between the second and third trials (Guerra-Balic et al., 2015), Nasuti et al. (2013) reported test-retest reliability of the modified-6MWT was ICC 0.98 in adults with intellectual disability (Nasuti et al., 2013), while Elmahgoub et al. (2012) observed an ICC of 0.82 in overweight adolescents with ID (Elmahgoub et al., 2012). Correlations between the six-minute walk distance (6MWD) and physiological parameters such as peak oxygen uptake (VO_2 peak) , with reported values of $r = 0.84$ (Guerra-Balic et al., 2015; Nasuti et al., 2013). Martínez-Aldao et al. (2019) examined a dance and music-based exercise program for adults with ID a significant improvement in their 6MWT performance after 10 weeks ($p < 0.05$), indicating enhanced cardiorespiratory fitness and mobility (Martínez-Aldao et al., 2019). Steyn et al. (2024) examined the effect of a walking, dance, and strength training intervention on functional ability in adults with ID. The 6MWT distance significantly increased post-intervention compared to the control group ($p < 0.05$) (Steyn et al., 2024).

2.4.2 Outcomes assessment of cognitive function

Cognitive function encompasses a set of mental processes that facilitate information acquisition, processing, and utilization, enabling individuals to engage in learning, decision-making, and problem-solving. It is commonly divided into hierarchical domains, ranging from fundamental sensory perception to higher-order executive functions, which regulate reasoning, planning, and cognitive control. Cognitive function is generally categorized into seven major domains, each essential for overall cognitive performance: sensation and perception, which involves detecting and interpreting sensory stimuli; attention and concentration, the capacity to focus on relevant information; memory, encompassing the processes of encoding, storing, and retrieving information; executive functioning, which includes planning, organizing, problem-solving, and behavior regulation; processing speed, reflecting the efficiency of cognitive task execution; language and verbal skills, the ability to understand and produce spoken and written communication; and visuospatial skills, which involve perceiving and manipulating spatial information (Harvey, 2019). In individuals with intellectual disabilities, cognitive function is frequently impaired across several of these domains, particularly in working memory, attention, processing speed, and executive function. These deficits significantly impact adaptive behavior and daily functioning, posing challenges in various aspects of life (Affes et al., 2023a; Hartman et al., 2010; Muñoz-Ruata et al., 2013).

1. Reaction time (RT)

Reaction time (RT) tests, specifically the Simple Reaction Time Test (SRT) and Choice Reaction Time Test (CRT), serve as effective measures of cognitive processing speed and executive function (Affes et al., 2021, 2023a; Borji et al., 2023). The SRT assesses the time taken for an individual to respond to a single, predefined stimulus, where participants press a button upon perceiving a visual or auditory cue. In contrast, the CRT involves multiple stimuli and requires participants to select the appropriate response corresponding to the presented stimulus, thereby evaluating decision-making speed and cognitive flexibility (Affes et al., 2021; Borji et al., 2023). Research indicates that RT tests, including both SRT and CRT, demonstrate high reliability in assessing cognitive processing speed. These measures are influenced by factors such as attention, vigilance, and neurological efficiency, making them valuable for tracking cognitive performance in populations with intellectual disabilities (ID). Individuals with ID typically exhibit slower RT due to deficits in information processing speed, working memory, and executive function (Affes et al., 2021; Borji et al., 2023). Moreover, the validity of reaction time as a measure of cognitive function is supported by findings showing significant correlations between RT and cognitive function ($r = -0.44$, $p < 0.001$) in both healthy individuals and patients. Additionally, a negative correlation was observed between RT and physical component summary scores in patients ($r = -0.42$, $p < 0.001$) (Jakobsen et al., 2011). Studies focusing on individuals with ID have established RT as a valid tool for measuring cognitive function, with one study indicating that running exercises at low (30% HRR) and moderate (60% HRR) intensities significantly decreased SRT ($p < 0.001$) and CRT ($p < 0.01$), with more pronounced improvements observed in the ID group ($p < 0.001$) (Affes et al., 2021). Furthermore, comparisons between the acute effects of aerobic and resistance exercises on RT and working memory revealed a significant reduction in RT after both exercise modalities ($p < 0.001$) (Borji et al., 2023).

2. Trail making test (TMT)

The Trail Making Test (TMT) is a neuropsychological examination tool that assesses cognitive processing speed and attention (Horvat et al., 2019; Sánchez-Cubillo et al., 2009). TMT-A necessitates that participants connect numbers in a sequential manner from 1 to 25, thereby measuring fundamental visual scanning and motor speed (Sánchez-Cubillo et al., 2009). The principal outcome of the assessment is the duration taken to complete, with extended completion times signifying potential cognitive deficits (Bednorz & Religa, 2023). The documented test-retest reliability for individuals experiencing intellectual disabilities shows ICC = 0.816 for TMT-A, with Cronbach's alpha scores between 0.80 and 0.90 (Horvat et al., 2019). Construct validity; TMT-A relates to visuoperceptual speed (Sánchez-Cubillo et al., 2009). Those demonstrating mild or moderate intellectual disabilities require considerably extended periods to complete TMT-A tasks when contrasted with individuals without disabilities, as the average time taken for TMT-A varies from 90.10 to 131.04 seconds ($p < 0.001$) (Horvat et al., 2019). Additionally, interesting relationships between total TMT scores and the montreal cognitive assessment (MoCA) were observed ($r = -0.28$, $p = 0.04$). In a research study involving elderly patients, those exhibiting mild cognitive impairment also revealed significantly extended completion times across all trails ($p < 0.01$) (Bednorz & Religa, 2023).

CHAPTER 3

METHODOLOGY

This research was conducted in two phases. Phase I testing of the Illuminated Nine-Square Dance Pad (INSP). Phase II investigated the effects of a 4-week INSP training program on functional ability and cognitive function in adults with intellectual disabilities. This chapter describes the materials and methods used in each phase.

Phase 1: Testing of the illuminated nine-square dance pad (INSP)

This phase involved testing the fully developed tool to evaluate the feasibility and safety of the Illuminated Nine-Square Dance Pad (INSP) before its actual use in the main research study. It simulates training scenarios with a sample group of three adults with intellectual disabilities (Appendix D).

The objectives of the device testing were as follows:

1. To examine whether participants could understand the instructions and follow the stepping procedures on the INSP (i.e., ease of use and correct task execution).

2. To verify the accuracy of the INSP system in detecting foot pressure, reported as percentage accuracy (%).

3. To assess movement safety during use, including the absence of slipping, loss of balance, or falls.

4. To obtain feedback from parents or caregivers regarding the appropriateness and perceived safety of the device.

Criteria for determining device feasibility and suitability

1. Participants correctly followed the stepping instructions in at least 80% of all trials.

2. The pressure-detection accuracy of the INSP system was not less than 90%.

3. No adverse events or falls were reported during the testing session.

4. Parents or caregivers reported that the device was appropriate, easy to use, and safe.

5. The testing results were used to refine the system settings, including the lighting program parameters and the pad sensitivity, before commencing the main trial.

The researcher designed, developed, and refined the prototype of the Illuminated Nine-Square Dance Pad (INSP) in collaboration with an expert team. The team included: (1) a physical therapist with more than 10 years of experience in providing care for individuals with intellectual disabilities; (2) faculty members from the Department of Physical Therapy, School of Integrative Medicine, Mae Fah Luang University; (3) a faculty member from the Department of Automation Robotics and Intelligence System Engineering, Faculty of Engineering, Khon Kaen University; and (4) a faculty member from the Department of Data Science and Health Informatics, Faculty of Medicine, Khon Kaen University.

Together, the research team selected appropriate materials and electronic components with particular attention to durability, safety, and responsiveness to pressure, to ensure accurate and reliable detection of stepping movements. In addition, the dimensions of the grid squares and the surface resistance were designed to suit adults with intellectual disabilities in terms of balance control, foot placement/stepping, and cognitive-perceptual abilities, thereby aligning the device with the physical characteristics and movement capacity of the target population (details are presented in Figures 3.1-3.2).

The stepping patterns used in this program were developed based on the concepts of Kao-ta (9-square step exercise) and Kao-ten (9-square dance exercise). The program employed a single-step format, in which both feet stepped into the same square. Participants were trained to move within a 3×3 grid, with each square measuring approximately 30 cm, to promote perceptual-motor coordination and dynamic balance in multiple directions. The INSP training program was designed according to principles of aerobic exercise, while simultaneously emphasizing perceptual-motor integration and multidirectional balance control (Atipas et al., 2019). Detailed information on the Nine Square Exercise performed using the illuminated nine-square dance pad is provided in Table 3.3.

Following the INSP device testing in three adults with intellectual disabilities, the results showed that:

1. All participants correctly followed the stepping instructions within the designated squares, with a mean accuracy of 100%, and were able to understand the training procedure after 1-2 rounds of explanation and demonstration.

2.The INSP pressure-detection system demonstrated a mean accuracy of 100% in triggering the LED responses, with no misdetection across grid squares.

3. No slipping, falls, or injuries were reported during the testing session.

4. Parents and caregivers reported that the guided illuminated cues helped participants identify the stepping locations more easily and appeared to increase their interest and engagement during practice.

Overall, the findings from Phase I indicated that the INSP was suitable for implementation in the main study in terms of user comprehension, system accuracy, and movement safety.

Data obtained during the device testing phase were not included in the primary outcome analysis. Instead, these findings were used to improve the device settings and procedures and to confirm the feasibility of the main trial, ensuring that the intervention could be delivered effectively and safely before commencing the primary training phase.

Phase 2: Effects of INSP Training in adults with Intellectual Disabilities

3.1 Study Design and Setting

This study was a Randomized Controlled Trial (RCT) with assessor blinding conducted at the rehabilitation ward of Rajanukul Institute, Bangkok, Thailand. Participants were adults with intellectual disabilities (ID) and were randomly assigned to two groups: an experimental group that performed Nine Square Exercise (NSE) on the illuminated nine-square dance pad (INSP) and a control group that performed Conventional Physical Therapy Exercise (CPE). The interventions in both groups were implemented by the researcher. Assessments were conducted at two time points: baseline and 4 weeks after training.

3.2 Participants

3.2.1 Sample size estimation

The sample size was estimated by formula: $n/group = \frac{2(Z_{\alpha}+Z_{\beta})^2\sigma^2}{(\mu_1-\mu_2)^2}$ (Chirawatkul, 2009) in which,

n = sample size / group

Z_{α} = Z-value for the type I error

Z_{β}= Z-value for the type II error

σ^2 = variance

μ_1 - μ_2 = mean difference

The sample size calculation was based on the study by Steyn et al. (2024), which examined the effects of a combined walking, dancing, and strength-training program on functional fitness in adults with intellectual disabilities. The 6-minute walk test (6MWT) was used as the cover all the effect of all outcomes for estimating the required sample size (Table 3-1). The confidence level set at 95% (significance level at 0.05) and the power of the test (1-β) at 80%. Thus, Zα = 1.65 and Zβ = 0.84.

$$n = \frac{2\ (1.65\ +\ 0.84)^2 \times 90^2}{69.3^2}$$

In summary, the calculated sample size was 21 participants per group, taking feasibility within the study period into account. After allowing for a 10% dropout rate, the adjusted sample size was 23 participants per group, resulting in a total of 46 participants.

Table 3.1 Sample size estimations

Outcome (Study)	**6MWT (Steyn et al., 2024)**	**6MWT (Martínez-Aldao et al., 2019)**	**TUG (DiPasquale & Kelberman, 2020)**
SD	90.2	80.50	1.86
μ_1 - μ_2	69.3	26.71	1.65
n/group	21	113	16

3.2.2 Details of participants with ID

Participants in this study were adults with intellectual disabilities (ID) who met the inclusion criteria. Eligible participants (and/or their legally authorized guardians) provided written informed consent prior to study participation. The recruitment criteria were as follows:

3.2.2.1 Inclusion criteria

1. Individuals diagnosed with mild to moderate intellectual disability according to the DSM-5 (Code 317, 318.0) or ICD-10 (F70–F71)

2. Had an IQ score of 35–69 (Jacinto et al., 2024; Pastula et al., 2012; Steyn et al., 2024), as confirmed by a developmental and behavioral pediatric specialist.

3. Had aged 18–35 years (male or female)

4. Had a Body Mass Index (BMI) of 18.5–39.9 kg/m² (Oviedo et al., 2014).

5. Able to walk independently without assistive devices (Martínez-Aldao et al., 2019; Pastula et al., 2012).

6. Able to follow simple instructions. Participants must be able to understand and respond to simple verbal commands required for functional and cognitive testing. This criterion was confirmed only if the participant met the first response option under item 16-22 of the initial screening form (Appendix C) (Martínez-Aldao et al., 2019; Steyn et al., 2024).

7. Normal hearing ability, or hearing that had been treated and restored to within the normal range.

8. Participants were willing to participate and provided informed consent, or consent was provided by a parent/guardian. (Pastula et al., 2012; Steyn et al., 2024).

9. Able to participate consistently in the study and likely to adhere to the study protocol (DiPasquale & Kelberman, 2020).

3.2.2.1 Exclusion criteria

1. Severe cardiovascular disease that limits exercise participation including uncontrolled hypertension, arrhythmia, history of recent myocardial infarction, or congenital heart defects (Affes et al., 2021; Borji et al., 2023).

2. Uncontrolled asthma or respiratory disease that restricted exercise participation (e.g., frequent dyspnea, exercise-induced exacerbations, or regular inhaler-dependent treatment).

3. Severe musculoskeletal impairments that prevent safe participation in exercise, including significant deformities, acute and chronic joint pain, recent fractures, or severe limitations in mobility. (Affes et al., 2021; Pastula et al., 2012).

4. Diagnosis of epilepsy or history of seizure disorders.

5. Uncorrected or severe visual impairments, including blindness, strabismus, or color blindness.

6. Aggressive behavior or inability to control emotions, posing a risk to themselves or others, as diagnosed by a doctor and documented in medical records. (Martínez-Aldao et al., 2019; Munn et al., 2023).

7. Psychiatric conditions requiring specialized treatment, such as schizophrenia or severe depression, as diagnosed by a doctor and documented in medical records.

3.3 Instrumentations

3.3.1 Illuminated nine-square dance pad (INSP)

1. Device name: Illuminated Nine-Square Dance Pad (INSP)

2. Model: INSP-2025 Prototype, Version 1.0

3. Developer/Manufacturer: Faculty of Engineering and Faculty of Medicine, Khon Kaen University, in collaboration with the School of Integrative Medicine, Mae Fah Luang University.

The INSP was a 90 × 90 cm dance pad with a 9-grid layout. Each 30 × 30 cm section was equipped with light sensors to provide an interactive dancing experience (Figure 3.1).

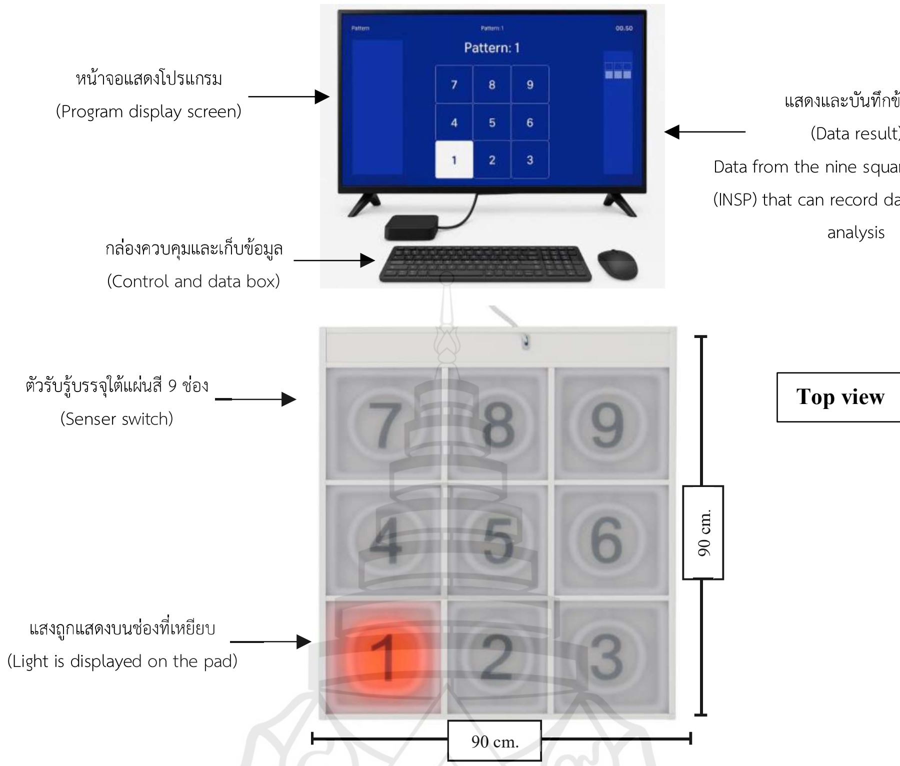
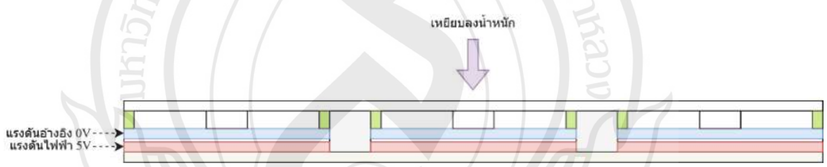


Figure 3.1 INSP (Top view) and its components



Note Blue (0 V reference) and red (5 V supply) layers made contact under foot pressure to complete the circuit and send a signal to the processing unit; side indicator lights are shown (green symbol)

Figure 3.2 Components of the INSP stepping pad.

The pad consisted of rubber sheets, acrylic panels, and PU foam to enhance user safety and comfort during exercise. Each of the nine squares (30 × 30 cm) was embedded with light sensors and equipped with resistive load cells to detect foot pressure and stepping accuracy. These sensors provided real-time color feedback displayed on the pad and on the screen (Figure 3.2).

The INSP system included a control box and an integrated data logger that recorded key variables, including the number of correct steps, completed patterns, and reaction time. Reaction time was recorded as the average response time to illuminated squares (milliseconds). The data were exported to Microsoft Excel files for subsequent statistical analysis (Figure 3.1).

3.3.2 Distance markers

3.3.3 Stopwatch

3.3.4 Standard chair

3.3.5 Traffic cone

3.3.6 Digital automatic blood pressure monitor and heart rate monitor

3.3.7 Computer with Reaction time test and Trail making test software

3.3.8 Data recording form (Appendix C)

3.4 Research Protocol

Research protocol for study: To compare effects of 4-week Nine Square Exercise and conventional PT exercise (see overview of the research in figure 3.3)

A Randomized Controlled Trial (RCT) with assessor blinding was conducted in eligible adults with intellectual disabilities (ID). The study procedures were implemented in the following sequence:

3.4.1 Participant screening: Participants were screened against the inclusion/exclusion criteria. The researcher collected baseline demographics and clinical data (sex, age, height, BMI, blood pressure, heart rate), assessed visual function, and screened basic cognitive-perceptual abilities, instruction following, and independence (Appendix C).

3.4.2 Informed consent: The study was explained to participants and their legally authorized guardians (or designated caregivers), and written informed consent was obtained.

3.4.3 Randomization: Stratified randomization was used to control for sex (male/female) and level of intellectual disability (mild/moderate). Participants were allocated to two groups: The experimental group (NSE), which performed Nine Square

Exercise using the INSP and the control group (CPE), which received Conventional Physical Therapy Exercise.

3.4.4 Baseline assessment: Functional ability was assessed using the 10MWT, TUG, FTSST, and 6MWT, while cognitive function was assessed using the SRT, CRT, and TMT-A.

3.4.5 Intervention: Both groups trained for 60 minutes per session, 2 days per week, for 4 weeks. Both interventions were conducted by the researcher, a licensed physical therapist, following standardized protocols.

3.4.6 Post intervention assessment: Functional ability and cognitive function were re-assessed at the end of the 4-week training period.

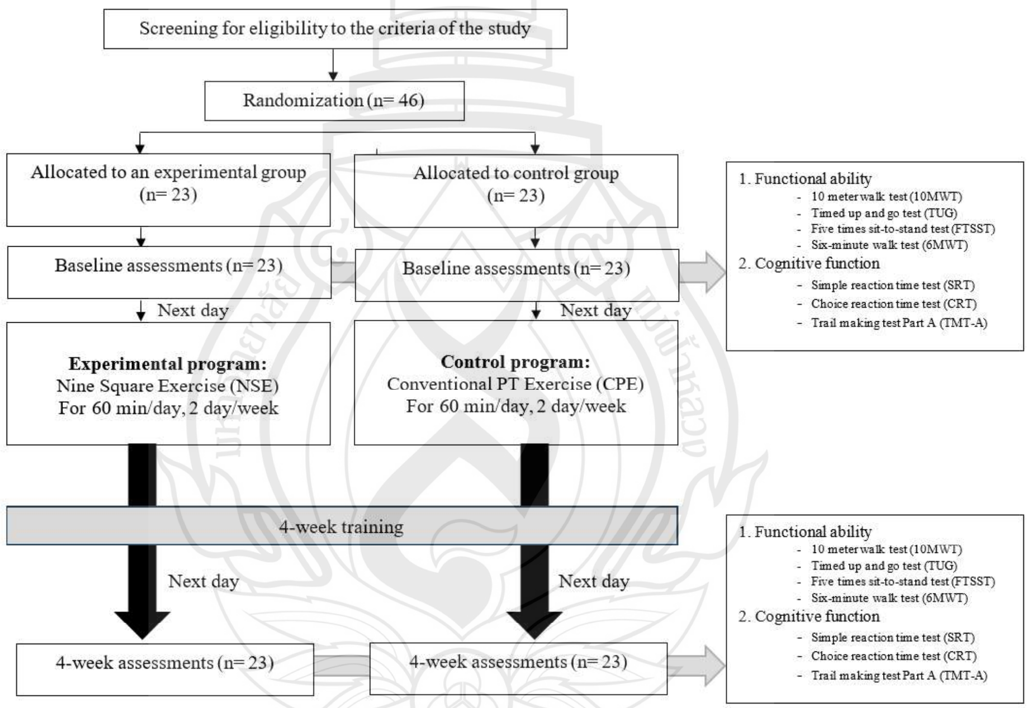


Figure 3.3 Flowchart to demonstrate research protocol

1. Illuminated nine-square dance pad (INSP) training

The steps for using the illuminated nine-square dance Pad (INSP) are as follows:

Table 3.2 Steps for using the illuminated nine-square dance Pad (INSP) (Appendix E)

Number of steps	Detail/Mode
1	The program will start with a Start Screen displaying the program logo and welcome message. Menu options: → Start: Enter the program → Exit: Close the program
2	Create or select a user profile For new users: → Create profile → Enter name/ID, age, and gender For existing users: → Login or select existing profile → Show brief statistics from last session and updated progress
3	Main Menu – Select Mode Testing Modes: → Ordinary mode Training Modes: → Ordinary mode → Random mode → Even number mode → Odd number mode
4	Training Screen (as described in Section 2.6) - 9-square dance pad lights up to indicate stepping points - Lights turn off when stepped correctly (1 point) - Timer: displays 45 minutes duration - Score: increases with correct steps

Table 3.2 (continued)

Number of steps	Detail/Mode
	- Instructions displayed (step direction, numbers, patterns) - Background music with a tempo ranging from 120 to 160 beats per minute (bpm)
5	End of Training Summary - Total score - Completed patterns - Reaction time - Options: → Save / Don't Save → Play Again / Print Summary / Back to Menu
6	Exit Program Menu options: → Options: Yes / No

2. Training mode of illuminated nine-square dance pad (INSP)

The session was structured into four main phases as follows:

Table 3.3 Training mode of illuminated nine-square dance pad (INSP)

Phase	Time	Activity Description
Warm-up	5 minutes	Light stretching was performed in a seated position to prepare the body for exercise. Stretching activities included: - Neck stretch: flexion–extension, lateral bending (15–20 sec each) - Shoulder stretch: cross-body arm stretch, shoulder rolls (10 reps each) - Trunk stretch: spinal twist, overhead reach with side bend (15–20 sec each)

Table 3.3 (continued)

Phase	Time	Activity Description
		- Lower body stretch: seated hamstring reach, one-leg forward stretch (15–20 sec each side)
Exercise Phase1 Skill-Based Stepping Patterns	30 minutes	Participants began from the bottom-left square (Position1) and performed stepping patterns progressively from simple to complex. Each pattern was repeated three times per set and performed with background music at a tempo of 120–160 bpm. Types of patterns included: - Straight lines (horizontal, vertical, diagonal) - L-shapes (small and large) - C-shapes, U-shapes, and V-shapes - Squares and rectangles - Triangles (small, large, right-angled) - Letter-shaped paths (S, M, W, Z, K, E, etc.) A total of 57 patterns were used across sessions.
Exercise Phase 2 Aerobic Phase	15 minutes	Participants engaged in rhythmic, aerobic movements performed continuously in sets of approximately 3 minutes each. Examples of movements include: - Marching in place - High-knee taps - One-leg stepping between grid squares - Side steps, grid walks - Jumping jacks, on-the-spot running
Cool down	10 minutes	- Slow marching in place (2–3 minutes) - Repeat stretches from the warm-up phase

The exercise protocol was supervised by the researcher following a standardized training protocol to ensure safety and consistency.

3. Conventional PT exercise (CPE)

The Conventional Physical Therapy Exercise (CPE) program used in this study was adapted from the standard exercise routine implemented at Rajanukul Institute. It was specifically designed to be appropriate for adults with intellectual disabilities. The session was structured into four main phases as follows:

Table 3.4 Conventional PT exercise (CPE)

Phase	Time	Activity Description
Warm-up	5 minutes	Light stretching was performed in a seated position to prepare the body for exercise. Stretching activities included: - Neck stretch: flexion–extension, lateral bending (15–20 sec each) - Shoulder stretch: cross-body arm stretch, shoulder rolls (10 reps each) - Trunk stretch: spinal twist, overhead reach with side bend (15–20 sec each) - Lower body stretch: seated hamstring reach, one-leg forward stretch (15–20 sec each side)
Strengthening exercises	15 minutes	Participants performed the following: 1. Seated hip flexions 2. Seated knee extensions 3. Standing Hip Extension 4. Standing Hip Abduction 5. Step up & down (15–25 cm step height) All exercises 1–5 are performed for 2–3 sets × 10 reps
Aerobic exercise	30 minutes	Participants performed treadmill walking at moderate intensity, with speed and incline individually adjusted to maintain heart rate levels not exceeding 70% of HRmax.
Cool down	10 minutes	- Slow marching in place (2–3 minutes) - Repeat stretches from the warm-up phase

The exercise protocol was supervised by the researcher following a standardized training protocol to ensure safety and consistency. This conventional program served as the control condition for comparison with the Nine Square Exercise (NSE) intervention in the experimental group.

3.5 Outcome Measures

Prior to data collection, the assessor received specific training on the procedures and protocols for each test. To verify measurement consistency, intra-rater reliability was assessed. The intraclass correlation coefficient (ICC) was calculated for each outcome variable, with an ICC of ≥ 0.75 considered acceptable. The ICC values were as follows: 10MWT = 0.91, TUG = 0.97, FTSST = 0.89, 6MWT = 0.96, SRT = 0.85, CRT = 0.83, and TMT-A = 0.81.

3.5.1 Functional ability assessments

1. 10-Meter Walk Test (10MWT)

Participants walked at a comfortable (normal) pace for a distance of 10 meters for a timed test, with a 2-meter acceleration period before the timed test began and a 2-meter deceleration period after the timed test ended. The test was performed three times, and the average walking speed was calculated from the three trials and expressed in meters per second (m/s) (Goh et al., 2024; Sánchez-González et al., 2023).

2. Timed Up and Go Test (TUG)

The participant sat in a standard armchair with their back against the backrest and both feet flat on the floor. Upon hearing the command “Go,” the participant stood up, walked forward for 3 meters, walked around a cone, turned, and returned to sit back in the chair in the original position. The timer started when the participant began to stand up and stopped when their back touched the backrest again. The test was performed three times, and the average time was recorded as the final result. (Blomqvist et al., 2012; DiPasquale & Kelberman, 2020; Enkelaar et al., 2013; Perrot et al., 2021; Salb et al., 2015).

3. Five Times Sit-to-Stand Test (FTSST)

The participant sat on a standard chair with their back against the backrest and feet flat on the floor, and crossed their arms over their chest. On the command "Go," the participant stood up fully and then sat down five times as quickly as possible. The total time to complete five repetitions was recorded using a stopwatch. Participants were required to fully extend their knees when standing and to make full contact with the chair when sitting. The test was performed three times, and the mean time across the three trials was used for data analysis. (Farías-Valenzuela et al., 2024; Oppewal & Hilgenkamp, 2020).

4. Six-Minute Walk Test (6MWT)

The participant was instructed to walk back and forth along a 10-meter corridor for six minutes. Participants were allowed to slow down or stop if necessary, but were encouraged to resume walking as soon as they felt able. The total distance covered (m) was recorded at the end of six minutes. (Casey et al., 2012; Goh et al., 2024; Guerra-Balic et al., 2015; Nasuti et al., 2013).

3.5.2 Cognitive function assessments

A computerized cognitive test battery was administered using a software-based tool developed by the Department of Physical Education, Ministry of Tourism and Sports, Thailand. The assessment included the Simple Reaction Time Test (SRT), Choice Reaction Time Test (CRT), and Trail Making Test Part A (TMT-A). (Yongtawee, 2020).

1. Reaction time test (RT)

The Simple Reaction Time Test (SRT) measured cognitive processing speed. During the test, participants focused on a computer screen and responded as quickly as possible when a red circle appeared in the center. They were instructed to press the "/" key on the keyboard using their index finger whenever the stimulus appeared. The test consisted of 20 stimulus presentations. Performance was analyzed based on the average response time of correct responses and the accuracy rate (%). (Affes et al., 2021, 2023a; Borji et al., 2023; Homsombat & Tunintaraarj, 2025; Yongtawee, 2020).

The Choice Reaction Time Test (CRT) assessed cognitive processing speed and decision-making efficiency by requiring participants to respond to different colored stimuli presented in random order on a computer screen. During the test, participants pressed the “Z” key with the left index finger when a red circle appeared, pressed the “/” key with the right index finger when a blue circle appeared, and did not press any key when a yellow circle appeared. The test consisted of 60 randomized trials, and participants were instructed to respond as accurately and as quickly as possible. Performance was analyzed based on the average response time of correct responses and the accuracy rate (%). (Affes et al., 2021, 2023a; Borji et al., 2023; Yongtawee, 2020).

2.Trail Making Test Part A (TMT-A)

Participants used a computer mouse to click numbered circles displayed on the screen in ascending order (1–25) as quickly and accurately as possible. The test began with a preparation screen; once started, the participant located and clicked number 1 and then proceeded sequentially through numbers 2 to 25. Each correctly selected number was connected by a red line, forming a continuous path. If an incorrect number was clicked, no line appeared, indicating an error. Performance was measured by completion time (s). (Homsombat & Tunintaraarj, 2025; Yongtawee, 2020).

3.6 Data Analysis

Descriptive statistics were used to summarize demographic data and baseline characteristics of the participants. Baseline between-group differences were compared using the independent-samples t-test for continuous variables and the chi-square (χ^2) test for categorical variables.

Within-group comparisons were performed using a paired t-test for normally distributed data and the Wilcoxon signed-rank test for non-normally distributed data. Between-group differences in in mean change were analyzed using an independent-samples t-test for normally distributed data and the Mann–Whitney U test for non-normally distributed data. In addition, analysis of covariance (ANCOVA) was performed to compare post-training outcomes between groups, with baseline values entered as covariates and group as the between-subjects factor. Statistical significance was set at $p < 0.05$.

CHAPTER 4

RESULTS

This research evaluated the effects of a 4-week Nine Square Exercise program using the INSP, compared with Conventional Physical Therapy Exercise, on functional ability and cognitive function in adults with intellectual disabilities. The results were presented in three parts including (1) participant characteristics, (2) functional ability outcomes and (3) cognitive function outcomes. Details of each topic were described below.

4.1 Participant Characteristics

A total of 46 participants with ID were average age 22 years, with normal BMI (26.43 kg/m²) included in the study (23 participants per group). The most of participants were female and had a moderate level of intellectual disability (52.2%), with Down syndrome (39.1%) representing the largest diagnostic subtype, and most participants had education below the secondary level. They exercised less than 2 days a week. Their baseline data showed no significant difference between the groups ($p > 0.05$, Table 4.1).

4.2 Functional Ability Outcomes

In the experimental group, training performance on the INSP showed a positive trend over the 4-week intervention period. Participants were able to complete more movement patterns, achieve higher training scores, and demonstrate greater progress during practice. In addition, their average reaction time during training became faster.

All participants in the experimental group could safely trained over the INSP without any adverse events. After training, these participants showed significant improvement in all functional outcomes after four-week training ($p < 0.001$, Table 4.2), but this improvement had in some outcome that included FTSST and 6MWT in the control group ($p = 0.032$, $p < 0.001$ respectively, Table 4.2). When compared the data between the groups, the improvement in the experimental group was significantly better than that in the control group only in 10MWT and TUG ($p < 0.01$, Table 4.2).

4.3 Cognitive Function Outcomes

All participants in the experimental group showed significant improvement in all cognitive outcomes from baseline to the four -week training, including significant changes in SRT, CRT, TMT-A, and accuracy for both SRT and CRT ($p < 0.05$, Table 4.3). While only accuracy of SRT and CRT were significantly improved in control group ($p = 0.032$, $p = 0.048$ respectively, Table 4.3). When comparison data between the groups, the improvement in the experimental group was significantly better than that in the control group only in SRT ($p < 0.001$, Table 4.3).

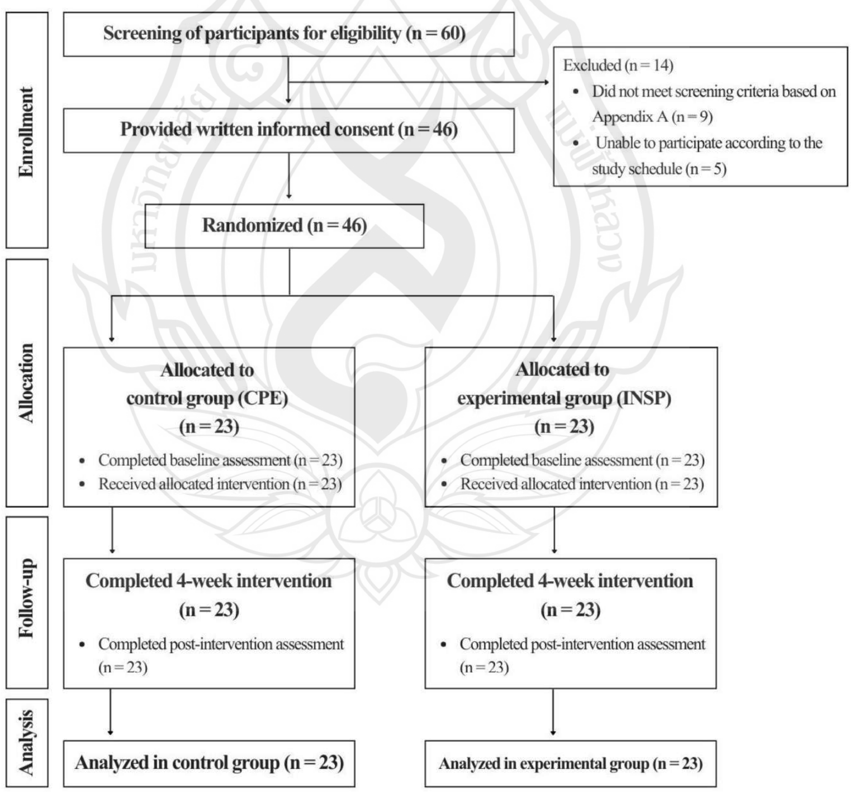


Figure 4.1 Participant flow diagram

Table 4.1 Baseline demographics of the participants (n = 46)

Variable	Total (n=46)	Control group (n= 23)	Experimental group (n= 23)	P-value [b]
Age: years [a]	22.02 ± 3.92	21.96 ± 3.84	22.09 ± 4.08	0.912
	(20.86, 23.19)	(20.29, 23.62)	(20.32, 23.85)	
Gender: Female, n (%)	26 (56.50)	12 (52.20)	14 (60.90)	0.562
IQ score [a]	49.65 ± 9.03	48.87 ± 9.53	50.43 ± 8.65	0.563
	(46.97, 52.33)	(44.75, 52.99)	(46.69, 54.18)	
Level of intellectual disability, n (%)				0.565
- Mild	22 (47.80)	10 (43.50)	12 (52.20)	
- Moderate	24 (52.20)	13 (56.50)	11 (47.80)	
Diagnostic subtype, n (%)				0.889
- Down Syndrome	18 (39.10)	8 (34.80)	10 (43.50)	
- Non-syndromic ID	13 (28.30)	7 (30.40)	6 (26.10)	
- Autism Spectrum Disorder	9 (19.60)	4 (17.40)	5 (21.70)	
- Attention Deficit Hyperactivity Disorder	6 (13.00)	4 (17.40)	2 (8.70)	

Table 4.1 (continued)

Variable	Total (n=46)	Control group (n= 23)	Experimental group (n= 23)	P-value [b]
Education, n (%)				0.570
- Primary	16 (34.80)	7 (30.40)	9 (39.10)	
- Lower secondary	19 (41.30)	10 (43.50)	9 (39.10)	
- Upper secondary	11 (23.90)	6 (26.10)	5 (21.80)	
Body Mass Index, kg/m² [a]	26.43 ± 5.81	26.86 ± 6.11	25.99 ± 5.60	0.619
	(24.70, 28.15)	(24.22, 29.50)	(23.70, 28.42)	
Systolic BP (mmHg) [a]	118.17 ± 15.71	115.78 ± 10.98	120.57 ± 19.29	0.307
	(113.51, 122.84)	(111.03, 120.53)	(112.22, 128.91)	
Diastolic BP (mmHg) [a]	71.96 ± 12.05	71.00 ± 11.17	72.91 ± 13.05	0.596
	(68.38, 75.54)	(66.17, 75.83)	(67.27, 78.56)	
Heart rate (bpm) [a]	87.43 ± 11.98	88.04 ± 10.28	86.83 ± 13.67	0.734
	(83.88, 90.99)	(83.60, 92.49)	(80.92, 92.74)	
Medication use, n (%)	30 (65.20%)	19 (82.60)	11 (47.80)	0.013

Table 4.1 (continued)

Variable	Total (n=46)	Control group (n= 23)	Experimental group (n= 23)	P-value [b]
Comorbidity: yes, n (%)	16 (34.80%)	7 (30.40)	9 (39.10)	0.546
Regular exercise, n (%)				0.142
- Never	39 (84.80%)	21 (91.30)	18 (78.30)	
- ≤ 2 days/week	5 (10.90%)	2 (8.70)	3 (13.00)	
- > 3 days/week	2 (4.30%)	0 (0.00)	2 (8.70)	
Experience with NSE: yes, n (%)	2 (4.30%)	1 (4.30)	1 (4.30)	1.000

Note Abbreviations: *BMI* Body Mass Index; *BP* Blood Pressure; *bpm* Beats Per Minute; *HR* Heart Rate; *ID* Intellectual Disability; *IQ* Intelligence Quotient; kg/m^2 Kilogram Per Square Meter; *n* number; *NSE* Nine Square Exercise.

[a] Data were presented as mean ± standard deviation (SD) for continuous variables.

[b] P-values were calculated using the independent-samples t-test for between-group comparisons of continuous variables and the chi-square test for categorical variables. Statistical significance was set at $p < 0.05$.

Table 4.2 Functional ability outcomes of participants in each outcome (n = 46)

Variables	Group	Baseline	4-weeks assessment	Mean difference [a]	P-value [a]	Between group difference (I-J) [b]	P-value [b]
10-Meter Walk Test (m/s)	Control group (I)	0.98 ± 0.26 (0.87, 1.09)	1.02 ± 0.36 (0.86, 1.17)	-0.04 ± 0.24 (-0.14, 0.07)	0.473		
	Experimental group (J)	0.95 ± 0.19 (0.87, 1.03)	1.17 ± 0.22 (1.07, 1.26)	-0.22 ± 0.12 (-0.27, -0.17)	<0.001***	-0.18 ± 0.06 (-0.29, -0.07)	0.003**
Timed Up and Go Test (s)	Control group (I)	10.91 ± 3.82 (9.26, 12.56)	10.58 ± 3.85 (8.92, 12.25)	0.33 ± 1.06 (-0.13, 0.79)	0.151		
	Experimental group (J)	11.08 ± 2.24 (10.11, 12.04)	9.35 ± 2.08 (8.45, 10.25)	1.73 ± 1.10 (1.26, 2.20)	<0.001***	1.39 ± 0.32 (0.76, 2.02)	<0.001***

Table 4.2 (continued)

Variables	Group	Baseline	4-weeks assessment	Mean difference [a]	P-value [a]	Between group difference (I-J) [b]	P-value [b]
Five Times Sit-to-Stand Test (s)	Control group (I)	13.17 ± 3.90 (11.48, 14.85)	12.45 ± 4.12 (10.66, 14.23)	0.72 ± 1.51 (0.07, 1.38)	0.032*		
	Experimental group (J)	13.62 ± 2.60 (12.50, 14.75)	12.63 ± 2.71 (11.46, 13.81)	0.99 ± 1.23 (0.46, 1.52)	<0.001***	0.25 ± 0.41 (-0.57, 1.08)	0.383
Six-Minute Walk Test (m)	Control group (I)	321.99 ± 86.97 (284.38, 359.60)	339.03 ± 92.20 (299.16, 378.90)	-17.03 ± 17.39 (-24.55, -9.51)	<0.001***		
	Experimental group (J)	319.23 ± 68.09 (289.79, 348.68)	338.57 ± 66.85 (309.66, 367.48)	-19.33 ± 24.19 (-29.79, -8.87)	<0.001***	-2.29 ± 6.28 (-14.96, 10.39)	0.718

Note Abbreviations: *m/s* meters per second; *s* seconds; *m* meters. Note: [a] Data were presented as mean ± SD (95% confidence intervals).

[a] The outcomes baseline and 4-weeks assessment were compared using a paired-samples t-test.

[b] The adjusted means from the Analysis of Covariance (ANCOVA) and Scheffé post hoc tests was used to compare between the groups.

* The superscripts indicated significant differences with the * p-value <0.05, ** p-value <0.01, *** p-value <0.001.

Table 4.3 Cognitive function outcomes of participants in each outcome (n = 46)

Variables	Group	Baseline	4-weeks assessment	Mean difference [a]	P-value [a]	Between group difference (I-J) [b]	P-value [b]
Simple Reaction Time (ms)	Control group (I)	607.87 ± 293.57 (480.92, 734.82)	596.65 ± 264.47 (482.29, 711.02)	11.22 ± 77.95 (-22.49, 44.92)	0.497		
	Experimental group (J)	597.22 ± 193.08 (513.72, 680.71)	477.83 ± 166.40 (405.87, 549.78)	119.39 ± 128.63 (63.77, 175.02)	<0.001***	110.26 ± 28.20 (53.39, 167.14)	<0.001***
Simple Reaction Time accuracy (%)	Control group (I)	89.13 ± 9.49 (85.03, 93.24)	92.39 ± 8.10 (88.89, 95.89)	-3.26 ± 6.84 (-6.22, -0.30)	0.032*		
	Experimental group (J)	93.91 ± 8.65 (80.17, 97.66)	96.74 ± 5.35 (94.42, 99.05)	-2.83 ± 5.18 (-5.07, -0.58)	0.016**	-1.66 ± 1.42 (-4.52, 1.20)	0.248

Table 4.3 (continued)

Variables	Group	Baseline	4-weeks assessment	Mean difference [a]	P-value [a]	Between group difference (I-J) [b]	P-value [b]
Choice Reaction Time (ms)	Control group (I)	625.48 ± 181.71 (546.90, 704.06)	613.57 ± 179.66 (535.88, 691.25)	11.91 ± 54.17 (-11.51, 35.34)	0.303		
	Experimental group (J)	708.48 ± 175.02 (632.79, 784.16)	653.65 ± 155.03 (586.61, 720.70)	54.83 ± 110.66 (6.97, 102.68)	0.027**	28.23 ± 24.90 (-21.98, 78.44)	0.263
Choice Reaction Time accuracy (%)	Control group (I)	67.26 ±15.12 (60.72, 73.80)	71.74 ± 15.59 (65.00, 78.48)	-4.48 ± 10.18 (-8.92, -0.03)	0.048*		
	Experimental group (J)	66.52 ± 16.08 (59.57, 73.48)	74.65 ± 15.87 (67.79, 81.51)	-8.13 ± 9.77 (-12.36, -3.90)	0.001**	-3.51 ± 2.85 (-9.24, 2.23)	0.225

Table 4.3 (continued)

Variables	Group	Baseline	4-weeks assessment	Mean difference [a]	P-value [a]	Between group difference (I-J) [b]	P-value [b]
Trail Making Test Part A (s)	Control group (I)	134.96 ± 46.56 (114.83, 155.09)	129.69 ± 51.41 (107.45, 151.92)	5.27 ± 22.76 (-4.57, 15.12)	0.279		
	Experimental group (J)	117.61 ± 43.66 (98.73, 136.49)	100.58 ± 47.12 (80.21, 120.96)	17.03 ± 21.39 (7.78, 26.28)	0.001**	12.15 ± 6.71 (-1.37, 25.68)	0.077
Trail Making Test Part A errors (n)	Control group (I)	0.83 ± 1.34 (0.25, 1.40)	0.70 ± 1.40 (0.09, 1.30)	0.13 ± 1.66 (-0.59, 0.85)	0.710		
	Experimental group (J)	0.30 ± 0.70 (0.00, 0.61)	0.30 ± 0.56 (0.06, 0.55)	0.00 ± 0.78 (-0.34, 0.34)	1.000	0.26 ± 0.32 (-0.38, 0.90)	0.416

Note Abbreviations: *ms* milliseconds; *s* seconds; *n* number of errors Note: [a] Data were presented as mean ± SD (95% confidence intervals).

[a] The outcomes baseline and 4-weeks assessment were compared using a paired-samples t-test.

[b] The adjusted means from the Analysis of Covariance (ANCOVA) and Scheffé post hoc tests was used to compare between the groups.

[*] The superscripts indicated significant differences with the * p-value <0.05, ** p-value <0.01, *** p-value <0.001.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Discussion

This study involved 46 participants, with a mean age of 22 years, with most having a moderate intellectual disability, and Down syndrome was the largest diagnostic subgroup. Most participants exercised fewer than two days per week. After a four-week INSP training program, the experimental group showed significant improvements all functional outcomes ($p < 0.001$), while the control group also improved on some measures (FTSST $p = 0.032$; 6MWT $p < 0.001$). Between groups, the experimental group demonstrated greater gains than controls specifically in 10-Meter Walk Test (10MWT) and the Timed up and go (TUG) test ($p < 0.01$). In cognitive outcomes, the experimental group improved all measures (SRT, CRT, TMT-A, and accuracy for both SRT and CRT; $p < 0.05$), whereas the control group showed improvements only in accuracy for SRT and CRT ($p = 0.032$ and $p = 0.048$, respectively). Between-group comparisons revealed a superior improvement in the experimental group only for SRT accuracy ($p < 0.001$).

Based on the research results, it is possible that the INSP program combines aerobic stepping with repeated multi-directional movements in a nine square pattern. Atipas et al. (2019) described nine square stepping and dance exercises as balance focused training that includes head, body and lower limb turning in multiple directions (forward, backward, left, and right). They also noted that dance-based movement patterns require higher coordination because they involve whole-body turns (Atipas et al., 2019). The improvement in TUG may also be related to the frequent weight shifting, quick direction changes, and turning practiced during INSP. According with previous studies which was reported by Jacinto et al. (2024) and Oviedo et al. (2014) conducted a 14-24week aerobic exercise by gymnasium-centered and outdoor training. Those in the gym-oriented group recorded substantial progress in lower limb strength and movement skills, confirmed by tests like the Timed Up and Go Test evaluation (Jacinto et al., 2024; Oviedo et al., 2014). These findings highlighted the importance of prolonged, well-structured exercise interventions for maximizing health benefits in individuals with ID. Thus, based on various posture in the experimental group, stepping speed and repetitive tasks promote better balance ability in adults with ID, consistent with the TUG test (improved from 11.08 ± 2.24 to 9.35 ± 2.08 s, $p < 0.001$). Although the causes are different, adults with intellectual disability and older adults may show similar limitations in balance and mobility at the functional level. Previous studies have reported poorer balance and mobility in persons with intellectual disability than in older adults from the general population (Enkelaar et al., 2013), and adults with intellectual disability may also present with features of accelerated aging (Oviedo et al., 2014). Therefore, evidence from older adults may be useful in supporting the interpretation of the present findings. For example, Wannapong et al. (2021), who reported a significant improvement in TUG, with a between-group difference of -2.29 s (95% CI -3.17 to -1.42; $p < 0.001$) after a five-week Nine Square Exercise program in older women (Wannapong et al., 2021). Kraiwong et al. (2021) also found significant improvements in TUG $p < 0.001$ in an eight-week physical cognitive program that included Nine Square Exercise in older adults with type 2 diabetes and balance impairment. These studies support the idea that repeated stepping in a structured grid can improve mobility, and this may help explain the improvements in TUG observed with INSP training.

In addition, previous evidence supports a strong association between TUG performance and gait speed. In adults with ID, TUG was correlated with the 10MWT ($r = 0.714$) (Enkelaar et al., 2013). While the improvements in walking-related outcomes in the present study were particularly consistent with the movement characteristics of the intervention. The INSP-based training involves repeated acceleration and deceleration, rapid changes of direction, and continuous stepping sequences, which are like the components needed for efficient gait and mobility in daily life. Accordingly, gait speed (10MWT) in the experimental group increased from 0.95 ± 0.19 to 1.17 ± 0.22 m/s ($p < 0.001$). In individuals with ID, walking performance depends on physical capacities, particularly lower-limb muscle strength, endurance and balance (Oppewal & Hilgenkamp, 2020; Sánchez-González et al., 2023).

Therefore, concomitant improvements in FTSST and functional mobility may have contributed to improvement in the 10MWT. The FTSST in the experimental group improved from 13.62 ± 2.60 to 12.63 ± 2.71 ($p < 0.001$) and 6MWT improved from 319.23 ± 68.09 to 338.57 ± 66.85 ($p < 0.001$). These improvements may be due to better lower-limb power and neuromuscular coordination, together with improved dynamic postural control during transitional movements (e.g., turning, initiating gait, and stopping). In addition, the rhythmic and dance like features of the program may have increased engagement and training adherence, enabling participants to sustain the intended intensity and volume over the 4-week period. The Nine Square Exercise in INSP places repeated load on the lower limbs, which may help improve leg strength and endurance both of which are important for walking performance. This explanation is supported by Puttipaibool et al. (2022), who found that 9-square dance exercise (9SDE) in adults healthy volunteers, resulted in significant improvements in fitness components, particularly cardiorespiratory endurance and leg strength, after a structured training program ($p < 0.05$) (Puttipaibool et al., 2022). Similarly, Phanpheng (2024) found that a Ram Thai with nine square dance program older adults with mild cognitive impairment, who may experience cognitive and functional limitations that are also common in adults with ID, increased 6-minute walk distance from 469.23 ± 51.3 to 485.85 ± 54.9 m ($p = 0.043$) and improved 30-s chair-stand performance from 14.83 ± 1.2 to 16.47 ± 1.9 repetitions ($p = 0.046$) (Phanpheng et al., 2024). This is supported by the study of Outayanik et al. (2017), who reported significant improvements in cardiovascular fitness (6-minute walk test 13.9 m, $p = 0.001$). Grid-based patterned stepping may also enhance sensorimotor processing by improving sensory-motor coordination and stimulating reaction time through repeated movement practice (Outayanik et al., 2017).

When comparing groups, the INSP group showed more improvement than the control group in 10MWT (between-group difference = -0.18 m/s, $p = 0.003$) and TUG (1.39 s, $p < 0.001$) after adjusting for baseline values. Although treadmill walking in the control group may seem similar to the 10MWT, the movement characteristics of the two tasks are not exactly the same. The 10MWT and TUG require not only forward walking, but also dynamic balance, weight shifting, speed adjustment, and movement control during functional tasks. The INSP program included repeated multidirectional stepping, quick direction changes, and visual cue-based responses, which may have provided more specific training for these outcomes. It is possible that this type of training improved balance quality, especially at the hip, knee, and ankle, as well as control of the center of mass during stepping. Repeated stepping with rhythmic and aerobic components may also have enhanced neuromuscular activation, motor unit recruitment, and movement timing, leading to more efficient gait performance. These adaptations may help explain why the experimental group showed greater improvement in 10MWT and TUG, whereas both groups improved in FTSST, possibly due to shared effects of repeated lower-limb activity and aerobic exercise on lower-limb muscle performance. This supports that INSP training provided more task specific practice for gait speed and mobility than the conventional program, particularly through repeated stepping patterns, frequent directional changes, and real-time cue-driven responses, which may explain why the strongest between-group effects were found in these two outcomes. The rhythmic and dance-like features of the program may have increased engagement and training adherence (Atipas et al., 2019; Chen et al., 2021). Previous studies suggests that dance-based exercise can support participation by improving well-being, social connection, and intrinsic motivation, which may help individuals maintain regular training (Puttipaibool et al., 2022). These findings are similar to studies that used dance and music-based exercise programs in people with ID. Martínez-Aldao et al. (2019) also reported that a dance and exercise program with music was feasible and safe for adults with ID, which supports the safety and practicality seen in the current program (Martínez-Aldao et al., 2019). DiPasquale and Kelberman (2020) reported that an integrative dance class improved mobility, with TUG decreasing from 9.11 ± 2.86 to 7.46 ± 1.86s ($p < 0.001$), and participants showed better mobility and stability (DiPasquale & Kelberman, 2020). In addition, Steyn et al. (2024) showed that a combined walking, dancing, and resistance training program in adults with intellectual disability, improved the eight-foot get-up-and-go test from 5.18 ± 0.9 to 4.90 ± 0.7s ($p < 0.01$). As a result, these findings support the idea that multi-component and dance-based movement programs (Atipas et al., 2019; DiPasquale & Kelberman, 2020) can enhance mobility outcomes in adults with ID (DiPasquale & Kelberman, 2020; Steyn et al., 2024), because TUG is related to gait speed (Enkelaar et al., 2013), better TUG may go along with faster walking on the 10MWT. This may help explain why both outcomes improved in the experimental group.

In contrast, the control group did show significant improvements in the FTSST and 6MWT. The 6MWT increased from 321.99 ± 86.97 to 339.03 ± 92.20 m ($p < 0.001$) and the FTSST improved from 13.17 ± 3.90 to 12.45 ± 4.12 s ($p = 0.032$). These findings support previous studies showing that aerobic exercise can improve aerobic capacity and muscle strength in adults with intellectual disability. Perrot et al. (2021) reported increase in 6MWT (23.62 ± 39.37 m; $p < 0.05$) and the 30-second chair stand test (2.67 ± 2.34 $p < 0.05$) following an exercise-based program (Perrot et al., 2021). Similarly, Jacinto et al. (2024) found that a 24-week exercise intervention was associated with significant 6MWT ($p = 0.007$) and sit to stand test ($p = 0.03$) (Jacinto et al., 2024). Despite, the control group did not show significant changes in 10MWT and TUG outcomes. 10MWT, the control group increased from 0.98 ± 0.26 to 1.02 ± 0.36 m/s ($p = 0.473$). Similarly, TUG changed from 10.91 ± 3.82 to 10.58 ± 3.85 s ($p = 0.151$). These smaller changes may be explained by differences in task specificity, intensity progression, or motivational engagement. Conventional PT exercises can improve FTSST and 6MWT, but they may include less practice of rapid stepping, frequent turning, and timed mobility tasks. As a result, improvements may transfer less directly to outcomes such as the 10MWT and TUG. Moreover, the changes observed in the present study may also be considered clinically meaningful when compared with from populations similar to adults with intellectual disability. For the Timed Up and Go Test (TUG), an MDC of 1.26 s has been reported in individuals with Down syndrome (Martin et al., 2017). The experimental group improved by 1.73 s, which was greater than the threshold and suggests a real improvement in functional mobility. In contrast, the control group improved by only 0.33 s, which was below the MDC. Similarly, for gait speed measured by the 10-Meter Walk Test (10MWT), an MDC of 0.188 m/s has been reported in adolescents and young adults with Down syndrome (Sánchez-González et al., 2023). In the present study, the experimental group improved by approximately 0.22 m/s, while the control group improved by only about 0.04 m/s. Therefore, the improvements in the experimental group may be considered meaningful in both statistical and clinical terms. However, clear MCID or MDC values for the

FTSST and 6MWT in adults with intellectual disability or closely related populations are still limited at present.

However, the between-group differences were not significant for outcomes that are related to 6MWT ($p = 0.718$) and FTSST ($p = 0.383$). This could be due to that both interventions provided a similar aerobic exercise and repeated lower limb use over the training period. The control program included strengthening exercises (e.g., seated hip flexion, knee extension, step up and down) and treadmill walking at moderate intensity. These components can reasonably improve FTSST and 6MWT, which are related to muscle endurance and cardiovascular capacity. While the experimental program included a 15-minute aerobic phase and continuous rhythmic stepping tasks. As a result, improvements in more general fitness domains may have been similar between groups. This explanation is supported by Puttipaibool et al. (2022), who compared 9-square dance exercise (30 minutes) with treadmill exercise and reported no significant between-group differences in physical fitness changes, while both programs improved cardiovascular endurance and leg strength (Puttipaibool et al., 2022). Therefore, these findings suggest that treadmill-based aerobic exercise and nine-square based stepping may produce similar improve in 6MWT and FTSST in both groups may reflect shared physiological adaptations from regular exercise, whereas the INSP may provide additional benefits for more task-specific mobility outcomes that depend on rapid stepping, direction changes, and turning such as the 10MWT and TUG.

The INSP training repeatedly requires rapid stimulus response coupling. During training, participants must detect an external cue (illuminated squares), rapidly initiate a stepping response and maintain movement timing within their response capacity. This repeated practice can enhance attention to relevant stimuli and faster response initiation, which are core determinants of reaction time performance. After the 4-week intervention, the experimental group showed a significant improvement in SRT, decreasing from 597.22 ± 193.08 to 477.83 ± 166.40 ms ($p < 0.001$). For SRT accuracy, both groups showed significant improvements (control: $89.13 \pm 9.49\%$ to $92.39 \pm 8.10\%$, $p = 0.032$; experimental: $93.91 \pm 8.65\%$ to $96.74 \pm 5.35\%$, $p = 0.016$). In the between-group comparison adjusted for baseline values, only SRT showed a significant difference the experimental group of 110.26 ± 28.20 ms ($p < 0.001$).

The significant improvement in SRT observed after the intervention is consistent with enhanced efficiency of early stage cognitive-motor processing, particularly rapid cue detection and response initiation. SRT is a basic measure of processing speed and reflects how quickly a participant can detect a stimulus, maintain attention, process the information, and initiate a motor response. Therefore, SRT is related mainly to attentional processing and processing speed rather than higher-order executive function. From a neurophysiological perspective, SRT depends on efficient sensory detection, response preparation, and motor initiation. (Affes et al., 2023b; Borji et al., 2023; Harvey, 2019). In individuals with ID, delayed movement responses are often linked to less efficient brain connectivity, resulting in slower sensory integration and reduced ability to adjust movements in changing environments (Hale et al., 2009; Mitic et al., 2021; Oppewal et al., 2018). This limitation is functionally relevant because stimulus recognition is critical even for basic locomotion; walking requires recognizing relevant cues to step in the correct direction, lift the foot to initiate the step, and swing the leg forward in the appropriate sequence (Horvat et al., 2016).

The INSP training repeatedly requires rapid stimulus response coupling. Participants must detect external cues (illuminated targets) and rapidly initiate stepping while maintaining timing within their response capacity. In addition, rhythm-based music (120-160 BPM) may have supported cognitive control during cue-driven stepping, helping participants stay focused on the targets and respond more consistently (Chen et al., 2021; Danso et al., 2025). In cognitive domain terms, this directly engages sensation and perception, where sensation involves detecting a stimulus and perception involves processing and integrating sensory information to identify a meaningful stimulus (Harvey, 2019). Such repeated practice plausibly strengthens the ability to use sensory information to guide movement execution. During movement, sensory feedback is continuously generated and integrated by the cortex to update the ongoing motor response (Horvat et al., 2016). Neurophysiologically, movement initiation and temporal organization depend on distributed motor networks cortical and subcortical motor areas including premotor and motor cortices, basal nuclei and cerebellum contribute to programming movement initiation (Horvat et al., 2016), while the supplementary motor area is involved in movement initiation and controlling movement timing, and the premotor area supports movement guided by sensory input (Muñoz-Ruata et al., 2013). Consistent with this, cerebellar mechanisms have been proposed to support performance by predicting anticipated stimuli, improving sensitivity to relevant cues, and contributing to precise timing functions across motor, sensory, and cognitive tasks (Diamond, 2000). Moreover, when task demands increase (e.g., in dual-task or divided-attention contexts), additional processing demands are placed on individuals with ID to control their movement responses (Horvat et al., 2016; Korkusuz & Top, 2023).

As SRT primarily reflects the efficiency of stimulus detection and response initiation, enhanced cue processing and motor initiation would be expected to shorten reaction time. This may help explain why SRT improved after 4 weeks of INSP training. The Nine Square Exercise on the INSP can be considered an aerobic stepping exercise. Therefore, it may support faster reaction time through exercise-related physiological activation. Evidence in individuals with ID shows that low to moderate intensity running (30% and 60% HRR) can improved reaction time. In a time-course study, Simple Reaction Time (SRT) decreased significantly after exercise at several time points: immediately after exercise (mean difference = 46.09 ms, $p < 0.001$) and it remained lower at 10 minutes (33.03 ms, $p < 0.001$), 20 minutes (33.94 ms, $p < 0.001$), and 30 minutes (17.41 ms, $p = 0.014$) post-exercise (Affes et al., 2021). The reduction was also greater after 60% HRR than 30% HRR (difference between intensities = 14.42 ms, $p = 0.007$), suggesting that a higher intensity within this range can lead to a larger improvement in processing speed (Affes et al., 2023). The acute exercise may enhance cognitive performance by increasing cerebral blood flow and by elevating neurochemicals alongside increased arousal and neural activation. The mechanisms that may shorten the time needed to detect a stimulus and initiate a response (Borji et al., 2023). Moreover, participating in aerobic exercise has demonstrated the ability to stimulate the production of neurotrophic elements, like Brain-Derived Neurotrophic Factor (BDNF), that bolster memory creation and cognitive strength. According with the study incorporating electroencephalography (EEG) have indicated a fall in frontal electrocortical activity, consequently improving cognitive control and attention processing (Vogt et al., 2013). For Choice Reaction Time (CRT), the same study reported significant decreases in the ID group at all measured time points: immediately post-exercise (78.75 ms, $p < 0.001$), 10 minutes (87.92 ms, $p < 0.001$), 20 minutes (78.67 ms, $p < 0.001$), and 30 minutes (79.25 ms, $p < 0.001$) post-exercise (Affes et al., 2023).

This evidence may help explain the pattern found in the present study. The experimental group showed a significant improvement in CRT from 708.48 ± 175.02 to 653.65 ± 155.03 ms ($p = 0.027$). For CRT accuracy, both groups showed significant improvements (control: 67.26 ± 15.12% to 71.74 ± 15.59%, $p = 0.048$; experimental: 66.52 ± 16.08% to 74.65 ± 15.87%, $p = 0.001$). However, the baseline-adjusted between-group comparison was not significant in CRT $p = 0.263$. A possible explanation is that CRT is more complex than SRT because it requires choosing the correct response, not only responding quickly. In the INSP program, illuminated targets appear repeatedly and participants must scan the squares, select the correct target, avoid wrong steps, and step in time. This provides practice in response selection and motor planning, which are important for CRT. At the same time, CRT may need a longer training period, a stronger progression of cognitive challenge, or a larger sample size to show a clear between-group difference. Previous evidence for reaction time (RT) improvements has been conducted in participants with mild ID and has quantified acute, post-exercise changes following a single exercise session. As such, the generalizability of these findings may be limited when applied to a mild-moderate ID and a 4-week training intervention, where baseline cognitive capacity, learning rates, and chronic adaptations may differ.

However, the control group did not show significant improvements in reaction time, including SRT improvement from 607.87 ± 293.57 to 596.65 ± 264.47 ms ($p = 0.497$) and CRT improvement from 625.48 ± 181.71 to 613.57 ± 179.66 ms ($p = 0.303$). A possible explanation is that the conventional PT exercise provided less task-specific practice for rapid cue detection and immediate response initiation. While the control intervention may improve functional ability (e.g., FTSST and 6MWT), it likely offers less practice in responding quickly to external cues, timed responses. (e.g., repeatedly detecting a visual cue and initiating a step as fast as possible). As a result, the training stimulus may have been insufficient to produce measurable changes in reaction time, which is highly sensitive to attentional engagement, cue-processing speed, and response initiation practice.

In addition, the baseline-adjusted between-group comparisons were not significant for SRT accuracy ($p = 0.248$) and CRT accuracy ($p = 0.225$). This may be because accuracy reflects response correctness, and participants typically aim to answer correctly at both baseline and 4-weeks assessment. Therefore, accuracy may show relatively small changes over time, especially when both groups benefit from similar practice related factors such as increased familiarity with computerized testing procedures, better understanding of task rules across repeated assessments, and improved sustained attention from regular structured participation. The accuracy outcomes often show considerable individual variability in people with ID (e.g., fluctuations in attention and response consistency), which can reduce statistical power and make between-group differences harder to detect over a 4-week intervention. In this context, reaction time may be a more sensitive indicator of training effects because it reflects the time needed to produce a correct answer. The present findings suggest that following training, participants were able to maintain correctness while requiring less time to generate correct answers, indicating improved efficiency of cognitive motor processing.

The INSP-based nine square training repeatedly requires participants to scan for a target, select the correct location, and respond with continuous stepping movements. During practice, participants must perform visual scanning, detect the cue target position, and execute an ongoing motor response under time demands. These training characteristics consistent with the TMT-A, which on processing speed, visual attention visual scanning, and visuomotor coordination to complete the task quickly (Horvat et al., 2019). This is consistent with the concept of cognitive domains, which categorizes of connecting sequences of numbers letters (Harvey, 2019). With high repetition, this type of cue-driven practice may improve fluency in scanning for relevant stimuli, sustaining attention throughout the task, and increasing the speed of initiating motor responses. This provides a plausible explanation for the significant improvement in the experimental group, where TMT-A completion time decreased from 117.61 ± 43.66 to 100.58 ± 47.12 s ($p = 0.001$). In addition, evidence in individuals with mild ID indicates that TMT Part-A performance is closely related to visual attention, visuomotor coordination, and time-pressured motor responding, supporting the interpretation that improvements in these component processes can lead to faster TMT-A performance (Gligorović & Buha-Đurović, 2010).

However, the control group did not show a significant change from 134.96 ± 46.56 to 129.69 ± 51.41 s ($p = 0.279$). The baseline-adjusted between-group comparison was not significant $p = 0.077$. No significant changes in TMT-A errors were observed within both group (control: 0.83 ±1.34 to 0.70 ±1.40 n $p = 0.710$; experimental 0.30 ±0.70 to 0.30 ±0.56 n $p = 1.000$) and between groups after baseline adjustment ($p = 0.416$). These findings indicate that the intervention effect was more evident for speed (time) than for accuracy (errors) on TMT-A. A possible explanation is that participants attempted to complete the task as accurately as possible at both baseline and follow-up, resulting in little change in error scores over time. Therefore, participants may have completed the task faster without a corresponding reduction in errors. It is also possible that the 4-week intervention primarily influenced processing speed, visual scanning, and response efficiency rather than accuracy-related components. In addition, TMT-A error scores may have been less sensitive to change because baseline errors were already low and showed limited variability. Furthermore, TMT-A mainly reflects visual scanning, attention, and processing speed, whereas more complex aspects of executive function may require cognitively more demanding measures. Therefore, the absence of change in TMT-A errors may reflect both the limited sensitivity of the error score itself and the relatively simple cognitive demands of TMT-A. More complex tasks, such as TMT-B or other set-shifting measures, may be better able to detect intervention-related changes in higher-order executive function.

A significant between-group difference in medication use was observed at baseline. This difference should be considered when interpreting the findings, as medication use may influence functional ability and cognitive function, including attention, reaction time, balance, and motor function. Therefore, the observed intervention effects should be interpreted with caution, as baseline differences in medication use may have acted as a potential confounding factor.

Limitations of this study should be considered. The sample size was small (n = 46), and participants varied in diagnostic subtype and IQ level, so subgroup specific effects could not be determined. In addition, content validity of the INSP program was not assessed and should be addressed in future studies. Outcomes were assessed only at the end of the 4-week program without longer-term follow-up, so it remains unclear whether the improvements are maintained over time and how well they translate to daily-life participation. A significant baseline difference in medication use was observed between groups, which may have acted as a confounding factor affecting the interpretation of the intervention effects. Another limitation was that the researcher conducted the interventions in both groups. Although this helped maintain consistency, it may have introduced performance bias. In addition, the cognitive assessment may not have fully captured higher-order executive function. Although TMT-A was useful for measuring visual scanning, attention, and processing speed, its error score showed low variability and may not have been sufficiently sensitive to detect subtle intervention-related changes over the 4-week period.

Future studies should include longer-term follow-up assessments to determine whether the benefits are maintained over time and translate to daily life participation. Larger studies are also needed to allow subgroup analyses, such as focusing on a specific diagnostic subtype or IQ level to clarify which groups benefit most. Future studies should use INSP data to examine how training dose and progression are associated with changes in functional ability and cognitive function outcomes. The content validity of the INSP program should be formally assessed to strengthen confidence in the intervention and measurement framework. In addition, including outcomes such as daily physical activity, participation in daily life, falls risk, and quality of life would clarify and support implementation in community and rehabilitation settings. In addition, future studies should more carefully control for medication use or include it as a covariate in the analysis to reduce potential confounding effects on functional and cognitive outcomes and involve more than one intervention provider, in order to reduce confounding and performance bias. Finally, future studies should also consider including more challenging measures of executive function, such as TMT-B or other tests of cognitive flexibility, set shifting, inhibition, or working memory, to better detect changes in higher-order cognitive processes. Including measures that are more sensitive to accuracy-related changes may also help clarify whether the intervention affects executive control in addition to processing speed.

5.2 Conclusion

This randomized controlled trial showed that a 4-week INSP-based Nine Square Exercise program is feasible and safe for adults with intellectual disabilities and can improve functional ability and cognitive function outcomes. The experimental group demonstrated significant improvements functional outcomes, and greater than the control group in 10MWT and TUG. Cognitive function also improved after INSP training, especially SRT measures, suggesting benefits in processing speed and cue-response ability. These findings support INSP-based Nine Square Exercise as a practical motor-cognitive training option that can serve as an appropriate rehabilitation approach and a community-based health promotion strategy to enhance functional independence and support healthier active living among adults with ID.

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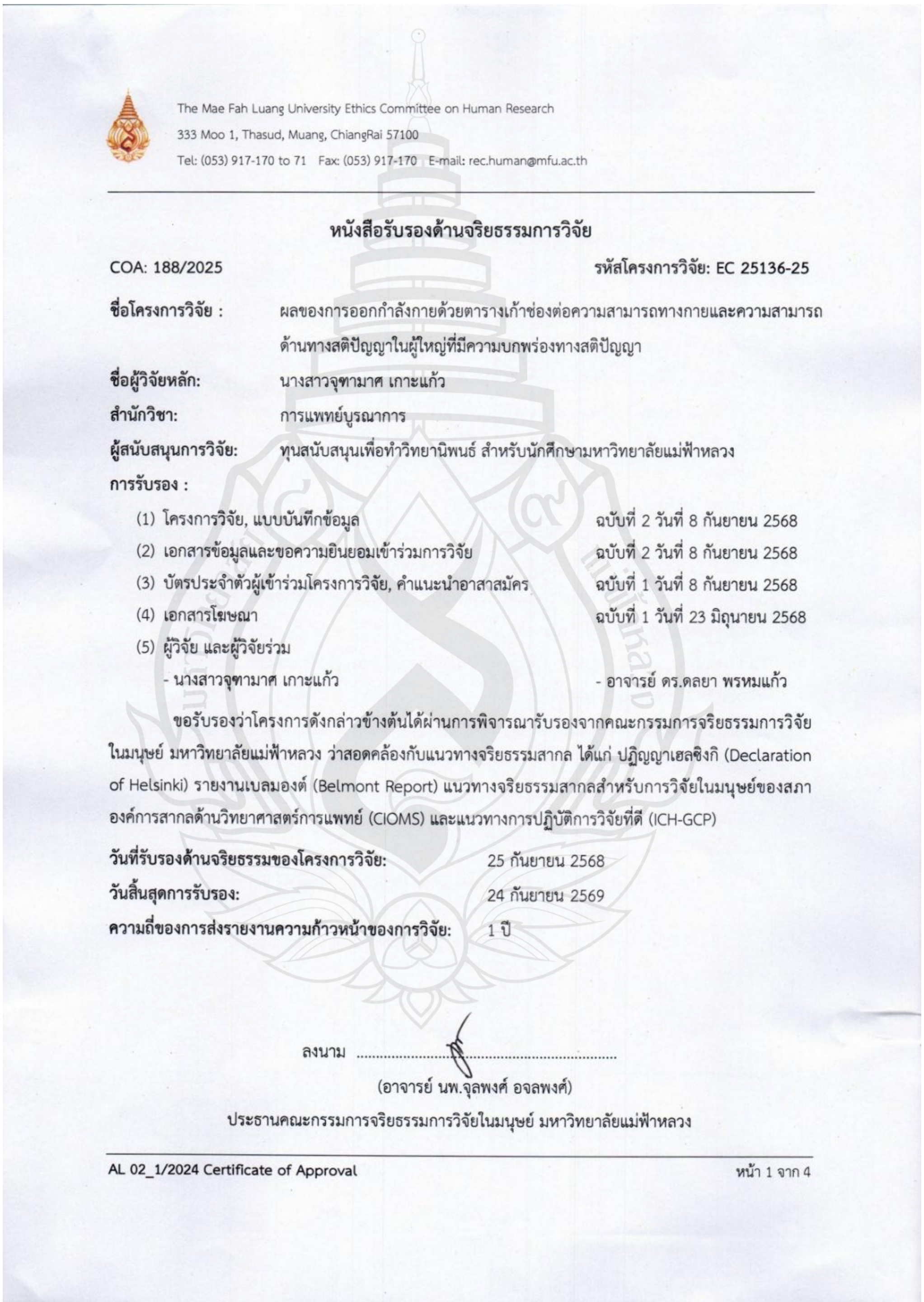
APPENDIX A

DOCUMENT CERTIFYING HUMAN ETHICS



The Mae Fah Luang University Ethics Committee on Human Research
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หนังสือรับรองด้านจริยธรรมการวิจัย

COA: 188/2025 **รหัสโครงการวิจัย: EC 25136-25**

ชื่อโครงการวิจัย : ผลของการออกกำลังกายด้วยตารางเก้าช่องต่อความสามารถทางกายและความสามารถด้านทางสติปัญญาในผู้ใหญ่ที่มีความบกพร่องทางสติปัญญา

ชื่อผู้วิจัยหลัก: นางสาวจุฑามาศ เกาะแก้ว

สำนักวิชา: การแพทย์บูรณาการ

ผู้สนับสนุนการวิจัย: ทุนสนับสนุนเพื่อทำวิทยานิพนธ์ สำหรับนักศึกษามหาวิทยาลัยแม่ฟ้าหลวง

การรับรอง :

(1) โครงการวิจัย, แบบบันทึกข้อมูล ฉบับที่ 2 วันที่ 8 กันยายน 2568
(2) เอกสารข้อมูลและขอความยินยอมเข้าร่วมการวิจัย ฉบับที่ 2 วันที่ 8 กันยายน 2568
(3) บัตรประจำตัวผู้เข้าร่วมโครงการวิจัย, คำแนะนำอาสาสมัคร ฉบับที่ 1 วันที่ 8 กันยายน 2568
(4) เอกสารโฆษณา ฉบับที่ 1 วันที่ 23 มิถุนายน 2568
(5) ผู้วิจัย และผู้วิจัยร่วม
- นางสาวจุฑามาศ เกาะแก้ว - อาจารย์ ดร.ดลยา พรหมแก้ว

ขอรับรองว่าโครงการดังกล่าวข้างต้นได้ผ่านการพิจารณารับรองจากคณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยแม่ฟ้าหลวง ว่าสอดคล้องกับแนวทางจริยธรรมสากล ได้แก่ ปฏิญญาเฮลซิงกิ (Declaration of Helsinki) รายงานเบลมองต์ (Belmont Report) แนวทางจริยธรรมสากลสำหรับการวิจัยในมนุษย์ของสภาองค์การสากลด้านวิทยาศาสตร์การแพทย์ (CIOMS) และแนวทางการปฏิบัติการวิจัยที่ดี (ICH-GCP)

วันที่รับรองด้านจริยธรรมของโครงการวิจัย: 25 กันยายน 2568
วันสิ้นสุดการรับรอง: 24 กันยายน 2569
ความถี่ของการส่งรายงานความก้าวหน้าของการวิจัย: 1 ปี

ลงนาม ....
(อาจารย์ นพ.จุลพงศ์ อจลพงศ์)
ประธานคณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยแม่ฟ้าหลวง

AL 02_1/2024 Certificate of Approval หน้า 1 จาก 4

Figure A1 Human Research Ethics Committees of Mae Fah Luang University

The Mae Fah Luang University Ethics Committee on Human Research
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ผู้วิจัยที่โครงการวิจัยผ่านการรับรองจากคณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยแม่ฟ้าหลวง ต้องปฏิบัติดังต่อไปนี้

(1) ดำเนินการวิจัยตามที่ระบุในโครงการวิจัยอย่างเคร่งครัด

(2) ใช้เอกสารข้อมูลและขอความยินยอมเข้าร่วมการวิจัย / แบบสอบถาม / แบบบันทึกข้อมูล / เอกสารประชาสัมพันธ์ ที่มีตราประทับของคณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยแม่ฟ้าหลวง เท่านั้น

(3) ผู้วิจัยต้องส่งรายงานความก้าวหน้าของการวิจัย (AP 05/2024) ตามระยะเวลาที่คณะกรรมการฯ กำหนด และ <u>ภายใน 30 วัน ก่อนหมดอายุการรับรอง</u> ในกรณีที่การวิจัยยังไม่เสร็จสิ้น ผู้วิจัยต้องส่งจดหมายขอต่ออายุการรับรอง

(4) เมื่อมีการแก้ไขเพิ่มเติมโครงการวิจัย ผู้วิจัยต้องส่งรายงานส่วนแก้ไขเพิ่มเติมโครงการวิจัย (AP 06/2024) และโครงการวิจัยที่มีการแก้ไขเพิ่มเติม เพื่อแจ้งให้คณะกรรมการฯ พิจารณารับรองก่อนดำเนินการตามที่ได้แก้ไขเพิ่มเติม (ยกเว้นในกรณีที่การแก้ไขเพิ่มเติมนั้นกระทำเพื่อความปลอดภัยของอาสาสมัคร)

(5) เมื่อมีเหตุการณ์ไม่พึงประสงค์ชนิดร้ายแรง "ในสถาบัน" ผู้วิจัยต้องส่งรายงานเหตุการณ์ไม่พึงประสงค์ชนิดร้ายแรง (AP 07/2024) ตามข้อกำหนดของ ICH-GCP

(6) เมื่อมีการเบี่ยงเบนหรือไม่ปฏิบัติตามโครงการวิจัยที่ได้รับการรับรอง ผู้วิจัยต้องส่งรายงานการการเบี่ยงเบนหรือไม่ปฏิบัติตามข้อกำหนด (AP 08/2024)

(7) เมื่อการวิจัยเสร็จสิ้น หรือ มีการยุติโครงการวิจัยก่อนกำหนดเวลาที่กำหนด ผู้วิจัยต้องส่งรายงานปิดโครงการวิจัย (AP 09/2024)

<u>หมายเหตุ</u> สามารถ Download แบบรายงานต่าง ๆ ได้ที่ https://ethic.mfu.ac.th

ข้าพเจ้าในฐานะ ผู้วิจัย ยินยอมที่จะปฏิบัติตามข้อกำหนดดังกล่าว

จุฑามาศ เกาะแก้ว
....

(นางสาวจุฑามาศ เกาะแก้ว)

วันที่ 1 ต.ค. 2568

AL 02_1/2024 Certificate of Approval หน้า 2 จาก 4

Figure A1 (continued)

The Mae Fah Luang University Ethics Committee on Human Research
333 Moo 1, Thasud, Muang, ChiangRai 57100
Tel: (053) 917-170 to 71 Fax: (053) 917-170 E-mail: rec.human@mfu.ac.th

CERTIFICATE OF APPROVAL

COA: 188/2025 **Protocol No: EC 25136-25**

Title: Effect of nine square exercise on functional ability and cognitive function in adults with intellectual disability

Principal investigator: Miss Juthamart Kohkaew

School: Integrative Medicine

Funding support: graduate thesis grant, Mae Fah Luang University

Approval:

1) Research protocol, Case record form — Version 2 Date September 8, 2025
2) Information sheet and informed consent documents — Version 2 Date September 8, 2025
3) Participant identification card, Advice for research participant — Version 1 Date September 8, 2025
4) Advertisement — Version 1 Date June 23, 2025
5) Principal investigator and Co-investigators
   - Miss Juthamart Kohkaew
   - Dr. Donlaya Promkeaw

The aforementioned documents have been reviewed and approved by the Mae Fah Luang University Ethics Committee on Human Research in compliance with international guidelines such as Declaration of Helsinki, the Belmont Report, CIOMS Guidelines and the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use - Good Clinical Practice (ICH - GCP)

Date of Approval: September 25, 2025

Date of Expiration: September 24, 2026

Frequency of Continuing Review: 1 year

....

(Jullapong Achalapong, M.D.)

Chairperson of the Mae Fah Luang Ethics Committee on Human Research

AL 02_1/2024 Certificate of Approval หน้า 3 จาก 4

Figure A1 (continued)

The Mae Fah Luang University Ethics Committee on Human Research
333 Moo 1, Thasud, Muang, ChiangRai 57100
Tel: (053) 917-170 to 71 Fax: (053) 917-170 E-mail: rec.human@mfu.ac.th

For research protocol approved by the Mae Fah Luang University Ethics Committee on Human Research (MFU EC), the investigators must comply with the followings:

1. Strictly conduct the research as required by the protocol.
2. Use only the information sheet, consent form, questionnaire, case record form and advertisement bearing the MFU EC stamp of approval.
3. Submit a progress report (AP 05/2024) for continuing review and for renewing the approval within 30 days before expiration date.
4. When there are changes of the protocol, the investigator must submit an amendment report (AP 06/2024) with amended protocol for MFU EC approval before implementing any changes in the research (unless those changes are required urgently for the safety of the research subjects).
5. When there is any unanticipated problem or serious adverse event, the investigator must submit a safety report (AP 07/2024) as set forth in the ICH-GCP.
6. When there is any deviation or non-compliance with the approved protocol, the investigator must submit a protocol deviation/non-compliance report (AP 08/2024).
7. When the research is complete or terminated, the investigator must submit a closing report (AP 09/2024).

Please go to https://ethic.mfu.ac.th **to download MFU EC forms for reporting.**

I, as an investigator, agree to comply with the above obligation.

....

(Miss Juthamart Kohkaew)

Date 1 ต.ค. 2568

Figure A1 (continued)

COA No. 11/2568

กรมสุขภาพจิต
สถาบันราชานุกูล

คณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ สถาบันราชานุกูล
กรมสุขภาพจิต กระทรวงสาธารณสุข
ที่อยู่ 4737 ถนนดินแดง แขวงดินแดง เขตดินแดง กรุงเทพมหานคร 10400

เอกสารรับรองโครงการวิจัย

คณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ สถาบันราชานุกูล ดำเนินการให้การรับรองโครงการวิจัยตามแนวทางหลักจริยธรรมการวิจัยในมนุษย์ที่เป็นมาตรฐานสากลได้แก่ Declaration of Helsinki, The Belmont Report, CIOMS Guideline และ International Conference on Harmonization in Good Clinical Practice หรือ ICH-GCP

ชื่อโครงการ : ผลของการออกกำลังกายด้วยตารางเก้าช่องต่อความสามารถทางกายและความสามารถด้านทางสติปัญญา ในผู้ใหญ่ที่มีความบกพร่องทางสติปัญญา
รหัสโครงการ : RI.IRB 012/2568_Exp
ผู้วิจัยหลัก : นางสาวจุฑามาศ เกาะแก้ว และคณะ
สังกัดหน่วยงาน : สำนักวิชาการแพทย์บูรณาการ มหาวิทยาลัยแม่ฟ้าหลวง
วิธีทบทวน : แบบเร็ว (Expedited Review)
รายงานความก้าวหน้า : ส่งรายงานความก้าวหน้าอย่างน้อย 1 ครั้ง/ปี หรือส่งรายงานฉบับสมบูรณ์หากดำเนินโครงการเสร็จสิ้นก่อน 1 ปี

เอกสารที่รับรอง :

1. แบบเสนอโครงร่างการวิจัย	ฉบับแก้ไขครั้งที่ 2 วันที่ 6 พฤศจิกายน 2568
2. เอกสารข้อมูลคำอธิบายสำหรับอาสาสมัครผู้รับการวิจัย	ฉบับแก้ไขครั้งที่ 2 วันที่ 6 พฤศจิกายน 2568
3. เอกสารแสดงความยินยอมเข้าร่วมโครงร่างการวิจัย	ฉบับวันที่ 7 ตุลาคม 2568
4. เอกสารแสดงความยินยอมเข้าร่วมโครงร่างการวิจัย สำหรับผู้แทนโดยชอบธรรม/ผู้ปกครอง	ฉบับแก้ไขครั้งที่ 1 วันที่ 27 ตุลาคม 2568
5. เครื่องมืองานวิจัย	ฉบับแก้ไขครั้งที่ 1 วันที่ 27 ตุลาคม 2568
6. ใบโฆษณาเชิญชวนอาสาสมัคร	ฉบับวันที่ 7 ตุลาคม 2568
7. ประวัติผู้วิจัย	ฉบับวันที่ 7 ตุลาคม 2568

ลงนาม (นายประเสริฐ จุฑา)
ประธานคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์

ลงนาม (นายทวีศักดิ์ สิริรัตน์เรขา)
ผู้อำนวยการสถาบันราชานุกูล

วันที่รับรอง : 12 พฤศจิกายน 2568
วันที่หมดอายุ : 11 พฤศจิกายน 2569

ทั้งนี้ การรับรองนี้มีเงื่อนไขดังที่ระบุไว้ด้านหลังทุกข้อ (ดูด้านหลังของเอกสารรับรองโครงการวิจัย)

Figure A2 Institutional Review Board of Rajanukul Institute

นักวิจัยทุกท่านที่ผ่านการรับรองจริยธรรมการวิจัยต้องปฏิบัติดังต่อไปนี้

1. ดำเนินการวิจัยตามที่ระบุไว้ในโครงร่างการวิจัยอย่างเคร่งครัด
2. ใช้เอกสารแนะนำอาสาสมัคร ใบยินยอม (และเอกสารเชิญเข้าร่วมวิจัยหรือใบโฆษณา ถ้ามี) แบบสัมภาษณ์ และหรือแบบสอบถาม เฉพาะที่มีตราประทับของคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์สถาบันราชานุกูล เท่านั้น และส่งสำเนาเอกสารดังกล่าวที่ใช้กับผู้เข้าร่วมวิจัยจริงรายแรกมาที่สำนักงานคณะกรรมการจริยธรรมการวิจัยในมนุษย์ สถาบันราชานุกูล เพื่อเก็บไว้เป็นหลักฐาน
3. รายงานเหตุการณ์ไม่พึงประสงค์ร้ายแรงที่เกิดขึ้นหรือการเปลี่ยนแปลงกิจกรรมวิจัยใดๆ ต่อคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ ภายใน 5 วันทำการ
4. ส่งรายงานความก้าวหน้าต่อคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ ตามเวลาที่กำหนดหรือเมื่อได้รับการร้องขอ
5. หากการวิจัยไม่สามารถดำเนินการเสร็จสิ้นภายในกำหนด ผู้วิจัยต้องยื่นขอความเห็นชอบใหม่ก่อนหมดอายุ 1 เดือน
6. หากการวิจัยเสร็จสมบูรณ์ผู้วิจัยต้องแจ้งปิดโครงการในแบบรายงานความก้าวหน้า/ขอต่ออายุการรับรองโครงร่างการวิจัย/ขอปิดโครงการวิจัย (AP 06.0)

Figure A2 (continued)

APPENDIX B

LITERATURE REVIEW TABLES OF EXERCISE INTERVENTIONS

Table B1 Aerobic and combined exercise interventions trial for intellectual disability

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Merrick, 2013)	A Pilot Study	9 overweights to obese older women (Mage = 57.2 ±7.5 years) with mild ID	Overweight/obese, age >50, able to follow simple orders	Down syndrome, cardiovascular disease, major psychiatric conditions, severe joint pain	aerobic exercise (treadmill walking)	25-45 minutes/session 3-5 times/week (32 weeks)	BMI, Subcutaneous Fat, Pelvic Circumference, Muscle Strength (Knee Extension)	Significant reduction in BMI (p = 0.005), subcutaneous fat (p = 0.005)
(Jacinto et al., 2024)	Quasi-experimental	21 adults (Mage = 43.04 ± 11.18 years) with mild to severe IDD	Adults with IDD, medically fit, able to perform the required movements and assessments, and no PE participation in the past 6 months.	Inability to commit for 6 months, profound IDD, inability to walk unassisted, contraindications to PE, or failure to provide informed consent.	exercise program (indoor/outdoor): strength and aerobic training	45 minutes/session 2 times/week (24 weeks)	TUG, Sit-to-Stand Test, 6-Minute Walk Test, QoL assessments	Significant improvement in IG for 30-s sit-to-stand (p = .03), timed up-and-go (p = .003), and 6-min walk test (p = .033). OG improved physical well-being (p = .017).

Table B1 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Son et al., 2016)	Quasi-experimental	9 adults (Mage = 42.33 ± 10.5 years) with intellectual disability	Overweight or obese, residing in residential care facility	Visual, auditory, neurological impairments that impede walking	walking exercise program	100 minutes/session 3 times/week (16 weeks)	BMI, Body Fat, Abdominal Fat, Waist Circumference, Muscle Strength, Flexibility	Significant reduction in BMI (-0.9, $p < .01$), body fat (-4.4%, $p < .01$), abdominal fat (-0.1%, $p < .01$), waist circumference (-2.2 cm, $p < .001$), and increased muscle strength (+8.5 sit-ups, $p < .001$) and flexibility (+4.5 cm, $p < .001$).
(Asonitou et al., 2018)	Quasi-experimental	38 adults (28-45 years) with mild ID	Age 28-45, mild ID, ambulatory	Musculoskeletal, cardiorespiratory issues, multiple disabilities	adapted physical activity program: strength, balance, flexibility, speed	60 minutes/session 2 times/week (16 weeks)	Eurofit Test Battery	Significant improvement in sit-up test ($p = 0.046$), standing broad jump ($p = 0.003$), sit and reach test ($p = 0.001$), shuttle run ($p = 0.001$), and plate tapping test ($p = 0.017$).

Table B1 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Oviedo et al., 2014)	Controlled clinical trial	92 adults (20-60 years) with mild to moderate ID	Age 20-60, mild to moderate ID, ambulatory	Severe to profound ID, contraindications to exercise, medications affecting response	combined aerobic, strength, and balance training	60 minutes/session 3 times/week (14 weeks)	VO2 peak, handgrip and leg strength, single leg stand test, sit-and-reach test, and BMI, body fat, waist circumference.	Significant improvements in VO2 peak ($p = .002$), handgrip strength ($p = .001$), leg strength ($p = .001$), sit-and-reach ($p = .001$), single leg stand ($p = .001$), and BMI reduction ($p < .05$).
(Perrot et al., 2021)	Randomized Controlled Trial	12 adults with Down syndrome, aged 35-64 years	Diagnosis of Down syndrome, aged over 35, able to follow instructions	Neuromusculoskeletal disorder, nonautonomous locomotion, inability to follow instructions	Wii-based exergame program	60 minutes/session 2 times/week (12 weeks)	Chair Stand Test, 6-Minute Walk Test, TUG, TUDS, Corsi, Barrage tests	Significant improvements in functional mobility ($p < .01$), muscular endurance ($p < .05$), and aerobic fitness ($p < .05$)

Table B2 Music and dance-based exercise interventions trial for intellectual disability

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Jo et al., 2018)	Randomized Controlled Trial	23 adults with intellectual disability, aged 18+	IQ 45-70, aged 18+, no musculoskeletal issues preventing exercise	Severe mobility impairment, medical contraindications for exercise, inability to perform activity	Band exercises and rhythmic activity	90 minutes/session 2 times/week (12 weeks)	Sit-up, self-efficacy, PA level, kcal/day, MVPA	Sit-up ($p = 0.028$), self-efficacy ($p = 0.022$), MVPA ($p = 0.015$), kcal ($p = 0.047$)
(DiPasquale & Kelberman, 2020)	Feasibility study	18 adults (Mage = 36.82 ± 15.38 years) with DD/ID	Age >18, DD/ID, physician approval	Participation in PT during study period, excessive absences	integrative dance class with college students including strength, flexibility, mobility, and balance exercises	60 minutes/session 2 times/week (12 weeks)	Lower extremity strength, knee extension test, Timed Up and Go test, Functional Reach Test	Significant improvements in lower extremity strength ($p < 0.001$), hamstring flexibility ($p < 0.001$), Timed Up and Go ($p = 0.001$), and Functional Reach Test ($p < 0.001$) Attendance: High adherence

Table B2 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Martínez -Aldao et al., 2019)	Feasibility study	30 adults (Mage = 36.37 ± 11.24 years) with mild to severe ID	Age >18, ID, able to follow simple instructions	Wheelchair dependence, health issues preventing participation	dance and exercise with music program	60 minutes/session 2 times/week (10 weeks)	Body mass index (BMI), cardiovascular fitness (6-minute walk test), muscular fitness (standing long jump test)	Significant improvements in BMI, cardiovascular fitness ($p < 0.005$), and muscular fitness ($p < 0.001$). Recruitment rate: 92.5%, Completion rate: 90%, Adherence: 76.6%, No adverse effects reported
(Munn et al., 2023)	Crossover design	44 adults with developmental disabilities (ASD, CP, DS, ID), aged 20.8–69.2 years	Aged 18+, diagnosed DD, able to follow two-step instructions	Severe physical disability, aggressive/self-harm behavior	Virtual Zumba® (normal and low tempo)	60 minutes/session 2 times/week (10 weeks with a 3 months washout)	Timed Up and Go, Six-Minute Walk Test	Significant improvements in TUG ($p < 0.001$) and 6MWT ($p < 0.001$).

Table B2 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Steyn et al., 2024)	Randomized controlled trial	42 adults (44.5±11.5 years) with intellectual disability	Age 18-65, able to follow instructions, parental/legal consent	Congestive heart disease, inability to comprehend instructions	walking, dancing, and strength training program	60 minutes/session 3 times/week (6 weeks)	Body mass, hip circumference, cardiovascular endurance (6MWT, 16-m PACER), functional ability, muscular strength, balance, and flexibility.	Significant improvements in body mass ($p < 0.05$), hip circumference ($p < 0.05$), cardiovascular endurance ($p < 0.01$), functional ability ($p < 0.01$), muscular strength ($p < 0.01$), balance ($p < 0.01$), and flexibility ($p < 0.05$).
(Chen et al., 2022)	Pilot Study	12 adults with Down syndrome, aged 15-29 years	Aged 15-29, diagnosed with DS, able to walk on treadmill, no severe health conditions preventing exercise participation	Mental age < 3 years, health issues flagged by PAR-Q	Treadmill walking with music/no music	24 min/session 1 session	Heart rate, walking steps	Increased HR ($p = 0.04$), % MaxHR ($p = 0.05$), steps ($p = 0.01$)

Table B3 Cognitive and physical exercise interventions trial for intellectual disability

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Korkusuz & Top, 2023)	Quasi-experimental	22 Individuals with mild intellectual disability, aged 7-14 years	Diagnosed with MID (IQ 50-70), no secondary impairments (vision, hearing, physical), no contraindications for exercise participation	Major health issues (heart disease, epilepsy, diabetes), use of medications affecting school participation, participation in structured exercise within the last 6 months	combined program of physical activity and attention training	100 minutes/session 2 times/week (14 weeks)	Attention test, visual retention, and motor proficiency (Bruininks-Oseretsky Test of Motor Proficiency-2nd version)	Significant improvements in attention parameters ($p < 0.05$), visual retention test scores ($p < 0.01$), fine motor precision ($p < 0.001$), fine motor integration ($p < 0.001$), manual dexterity ($p < 0.001$), and upper-limb coordination ($p < 0.001$).
(Wang et al., 2023)	Randomized Controlled Trial	30 adults with mild intellectual disability, aged 30-40 years	IQ 50-69, no prior badminton training, no chronic disease, no physical disabilities	ADHD, severe cardiovascular disease, severe trauma	Badminton training program	60 minutes/session 3 times/week (12 weeks)	Stroop test, n-back task	Significant improvement in inhibitory control ($p < 0.05$) and working memory ($p < 0.05$)

Table B3 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Pastula et al., 2012)	Quasi-experimental	14 young adults (19.46±1.3 years) with mild to moderate IDs	Mild to moderate ID, age 18-25, ambulatory, able to perform exercise, no recent history of physical training	Severe cognitive impairment preventing exercise participation, major cardiovascular disease, inability to follow instructions	moderate-intensity exercise program: circuit training, aerobic dancing, adapted sports	45 minutes/session 3 times/week (8 weeks)	Aerobic fitness (YMCA step test), cognitive function (Woodcock-Johnson III cognitive subtests: visual matching, decision speed, and pair cancellation)	Significant improvement in aerobic fitness (+17.5%, $p < 0.002$) and all cognitive function tests ($p < 0.002$), with a 103% increase in processing speed.
(Vogt et al., 2013)	Cross-over design	11 Adolescents with intellectual and developmental disabilities (IDD), aged 16 ± 1.34 years	Right-handed, able to differentiate colors and shapes, no severe health conditions preventing participation	Inability to differentiate colors and shapes, severe neurological disorders	10-minute moderate cycling exercise vs. 10-minute relaxation (sitting while listening to music)	10 minutes/session 1 session per condition 2 sessions (with 24-hour washout)	Reaction time (RT), EEG-based electrocortical activity (N2 latency and amplitude)	Significant improvement in reaction time ($p < 0.01$), decreased N2 latency ($p < 0.01$), and decreased electrocortical activity in the medial frontal gyrus ($p < 0.001$).

Table B3 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Huang et al., 2020)	Randomized Controlled Trial	100 Children aged 10-13 years with and without learning disabilities (LD)	Diagnosed LD (IQ 81-102), academic achievement in 5th-10th percentile, ability to follow test instructions	Autism Spectrum Disorder (ASD), ADHD, major neurological disorders	30-minute moderate-intensity treadmill running (50-70% HR reserve) vs. watching an exercise-related video	30 minutes/session 1 session	Sustained attention (DAUF test), discriminatory ability (Determination test), reaction time, accuracy rate	significant improvements in sustained attention and discrimination ($p < 0.001$), reaction time ($p < 0.01$), and accuracy ($p < 0.01$) compared with controls, with greater gains in the LD than typically developing (TD) group.
(Affes et al., 2021)	Quasi-experimental	24 Individuals with mild intellectual disability (IQ 50-70)	Males with mild intellectual disability, matched for age, height, weight, no prior structured physical training	Metabolic, musculoskeletal, cardiovascular, respiratory diseases, hearing and vision problems	treadmill running at low intensity (30% HRR) and moderate intensity (60% HRR), performed in randomized order	30 minutes/session 2 sessions (low-intensity and moderate-intensity) 2 sessions with a 24-hour washout	Visual reaction time (Simple RT, Choice RT), auditory simple reaction time (ASRT), working memory (Corsi test)	Significant improvements in Simple RT ($p < 0.001$), Choice RT ($p < 0.01$), ASRT ($p < 0.001$), and Working Memory ($p < 0.01$) after both intensities. Greater ASRT improvement at low intensity ($p < 0.05$).

Table B3 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Affes et al., 2023a)	Crossover design	24 Males with mild intellectual disability (ID), aged 15.25 ± 2.76 years	IQ between 50-70, no secondary impairments (vision, hearing, physical), no structured physical activity	Down syndrome, metabolic, musculoskeletal, cardiovascular, respiratory diseases, hearing and vision problems.	Two treadmill running intensities: low (30% HRR) and moderate (60% HRR), each performed in a randomized order.	30 minutes/session 1 session per condition 2 sessions with a 24-hour washout	Visual simple reaction time (VSRT), visual choice reaction time (VCRT), auditory simple reaction time (ASRT), motor speed (Finger-Tapping Test).	Significant improvement in VSRT ($p < .001$), VCRT ($p < .001$), ASRT ($p < .001$) and motor speed ($p < .001$) after both intensities. Greater ASRT improvement after 30% HRR than 60% HRR ($p < .05$). Effect maintained for over 30 minutes post-exercise.

Table B3 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Borji et al., 2023)	Crossover Design	13 Male adolescents with mild intellectual disability (IQ 50-70)	No secondary impairments (vision, hearing, physical), no structured physical activity	Down syndrome, metabolic, musculoskeletal, cardiovascular, respiratory diseases, hearing and vision problems	30-min. aerobic exs. (treadmill running at 60% HRR) vs. 20-min. resistance exs. (2 sets of 10 reps at 70% 10-RM for major muscle groups), compared to a control session (watching a sports video)	30 minutes/session (aerobic), 20 minutes/session (resistance) 1 session per condition 3 sessions (each condition performed in a randomized order, separated by 3-day washout)	Simple reaction time (SRT), choice reaction time (CRT), working memory (Corsi block-tapping test)	Significant improvement in SRT ($p < .001$) and CRT ($p < .001$) after both AE and RE, with greater improvement after RE. Significant improvement in working memory ($p < .001$) only after AE, with no effect from RE or control.

Table B4 Nine square exercise interventions trial

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Puttipaibool et al., 2022)	Randomized Controlled Trial	33 Healthy adults aged 18–59 years with BMI 18.5–24.9 kg/m²	No current or past smoking, no regular alcohol use, no difficulties with ambulation, no cardiovascular medication use	Participants who failed to complete ≥70% of sessions, underlying health conditions affecting exercise participation	Three groups: 1) 9-Square Dance Exs. 8 min (9SDE-8) 2) 9-Square Dance Exs.30 min (9SDE-30) 3) Treadmill Exercise (TME)	8 or 30 minutes/session (9SDE), 30 minutes/session (TME) 3 times/week (12 weeks)	Physical fitness (step test, lung capacity, leg strength, flexibility), Quality of Life (EQ-5D-5L questionnaire)	9SDE-30 and TME significantly improved cardiovascular endurance, leg strength, and flexibility ($p < 0.05$). 9SDE-8 significantly improved quality of life utility score ($p < 0.05$)
(Phanpheng et al., 2024)	Quasi-experimental	67 Elderly individuals (aged 60-79 years)	No severe physical or cognitive impairments, ability to perform physical activities, ability to provide informed consent	Individuals with severe cardiovascular diseases, severe dementia, musculoskeletal disorders preventing participation	Two groups: 1) Ram Thai with Nine Square Dance (RTND) 2) Brisk Walking Exercise (BWE)	45 minutes/session 3 times/ week (12 weeks)	Body composition, VO2max, lower limb strength, 6MWT, upper limb flexibility, balance and agility (TUG), cognitive function (MoCA-B, Thai version)	Significant improvements in RTND group for flexibility ($p = .001$), cognitive function ($p = .001$), and lower limb strength ($p = .046$). Both RTND and BWE improved VO2max ($p = .029$), body fat reduction ($p = .012$), and mobility ($p = .037$).

Table B4 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Outayanik et al., 2017)	Quasi-experimental	15 Healthy Thai older adults (aged 60-75 years)	No severe physical or cognitive impairments, ability to perform physical activities, ability to provide informed consent	Uncontrolled hypertension, severe cardiovascular diseases, diabetes, symptomatic cardiorespiratory disease, severe renal or hepatic disease, uncontrolled epilepsy, progressive neurological disease, chronic disabling arthritis	Nine Matrices Exercise (NME) Program (stepping exercises on a 9-square mat, incorporating stretching, aerobic movement, and bodyweight training)	30-60 minutes/session 5 times/week (8 weeks)	Body composition (weight, BMI), cardiovascular fitness (6-min walk test), muscular strength (arm curl, leg squat), flexibility (shoulder, lower back & hamstring), agility & balance (8-ft up-and-go test)	Significant improvements in weight (-2.5%, $p < 0.001$), BMI (-2.5%, $p < 0.001$), cardiovascular fitness (+13.9%, $p = 0.001$), muscular strength (arm curl +45.9%, $p = 0.001$; leg squat +42.8%, $p = 0.001$), flexibility (shoulder +9.8%, $p = 0.006$; lower back & hamstring +15.0%, $p = 0.001$), agility & balance (-3.9%, $p = 0.003$)

Table B4 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Atipas et al., 2019)	Prospective Pilot Study	11 Patients diagnosed with balance disorders attending the outpatient clinic at Siriraj Hospital	Age 18-70 years, persistent balance disorder symptoms for over 4 weeks, abnormal condition in at least one post urography test	Neuromuscular disorders preventing proper performance, central cause of balance disorders, psychiatric conditions, or specific treatable diseases (e.g., BPPV)	Kao-Ta (9-square step exercise) and Kao-Ten (9-square dance exercise), 3 minutes of Kao-Ta followed by 2 minutes of Kao-Ten, performed to music	5 minutes/session 2 times/week 8 weeks (minimum of 45 sessions)	Composite equilibrium score, Visual Analog Scale (VAS) for balance symptom severity	Significant improvement in composite equilibrium score (64.4 ± 8.1 to 73.8 ± 10.2, $p < 0.01$), reduction in VAS balance symptom severity (median 4 to 2, $p = 0.028$)
(Kraiwong et al., 2021)	Randomized Controlled Trial	37 Older adults (≥60 years) with Type 2 Diabetes Mellitus (T2DM) and balance impairment	Diagnosis of T2DM, balance impairment (Timed Up & Go >10 sec), ability to participate in physical activity	Stroke, Parkinson's disease, lower limb amputation or joint replacement, severe musculoskeletal conditions, uncontrolled hypertension or symptomatic hypotension	Physical-cognitive training (NSE combined with resistance training and cognitive training for memory, attention, and executive functions)	45-60 minutes/session 3 times/week (8 weeks)	Balance (Timed Up & Go, Alternate Step Test), Muscle Strength (hip, knee, and ankle strength), Activities of Daily Living (ADL), Fall Rate	Significant improvements in balance (TUG: $p<0.001$, AST: $p<0.001$), muscle strength (hip, knee, ankle: $p<0.05$), and ADL ($p=0.018$). Falls rate was similar between groups at 12 months.

Table B4 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Thanasootr et al., 2022)	Randomized Controlled Trial	18 Male collegiate athletes with chronic ankle instability (CAI)	History of at least one lateral ankle sprain (LAS), initial LAS occurred >12 months prior, at least two episodes of "giving way" in the past 6 months, CAIT score ≤25, FAAM-Sports score ≤85%	Acute lower extremity injury within the last 3 months, prior surgery or fracture in lower extremities, visual, vestibular, or neurological disorders affecting balance	Nine-Square Exercise	30 minutes/session 3 times/week (6 weeks)	Postural control (Modified Star Excursion Balance Test, Foot Lift Test), Self-reported ankle stability (Cumberland Ankle Instability Tool), Functional ability (Foot and Ankle Ability Measure-ADL & Sports)	Significant improvements in dynamic postural control ($p < .001$), self-reported ankle stability ($p = .002$), and functional ability ($p < .05$) in the Nine-Square Exercise group compared to control. Static postural control improved in both groups ($p = .018$).
(Wannapong et al., 2021)	Randomized Controlled Trial	34 Older women	Aged 60-79 years, BMI 18.5-29.9 kg/m², TUG test time >13.5 seconds (fall risk)	Severe cognitive impairment, use of gait aid, participation in other exercise programs	Nine-Square Exercise (experimental group) vs. Health Education (control group).	30 minutes/session 3 times/week (5 weeks)	Balance (Timed Up and Go Test, TUGT)	Significant improvement in balance (TUGT, $p < 0.001$), mean difference of -2.29 sec (95% CI -3.17 to -1.42).

Table B4 (continued)

Study	Study Design	Participant Selection Criteria	Inclusion Criteria	Exclusion Criteria	Intervention	Training Duration	Outcome Measures	Results
(Udom et al., 2022)	Randomized Controlled Trial	24 Overweight female undergraduate students, aged 18-25 years	BMI between 25.0-29.9 kg/m², aged 18-25 years, normal vision and hearing	History of musculoskeletal or neurological disorders, history of back/lower limb surgery, presence of joint diseases	Nine-Square Step Dance Exercise (experimental group) vs. Self-Practice Exercise with Leaflets (control group).	30 minutes/session 3 times/week (4 weeks)	Postural stability (Star Excursion Balance Test, SEBT)	Significant improvements in SEBT scores in all 3 directions: anterior ($p = 0.024$), posteromedial ($p < 0.001$), and posterolateral ($p < 0.001$)

APPENDIX C

DATA RECORDING FORM (IN THAI)

รับรองโดยคณะกรรมการจริยธรรมการวิจัยในมนุษย์
สถาบันราชานุกูล
รหัสโครงการวิจัย RI .IRB 012 / 2568 - Exp
วันที่รับรอง 12 พฤศจิกายน 2568

แบบบันทึกข้อมูลการวิจัย (Data recording form)

แบบสัมภาษณ์และบันทึกข้อมูลพื้นฐานส่วนบุคคล

ส่วนที่ 1 แบบสัมภาษณ์และบันทึกข้อมูลพื้นฐานส่วนบุคคล (โดยผู้วิจัยในวันแรกที่พบอาสาสมัคร)

คำชี้แจงการบันทึกข้อมูล ผู้วิจัยเป็นผู้บันทึกข้อมูลในแบบฟอร์มนี้ โดยการสัมภาษณ์ครู ผู้ปกครองหรือผู้ดูแล และจากความสามารถในกิจกรรมประเมิน รวมถึงการเก็บข้อมูลจากเวชระเบียน โดยใช้คำถามที่เป็นตัวเลือก และจดบันทึกข้อมูลที่ได้จากการสัมภาษณ์/สังเกตจากอาสาสมัคร รวมถึงข้อมูลจากเวชระเบียน โดยให้กาเครื่องหมายถูก (/) ในช่อง ( ) หน้าตัวเลือกที่ตรงกับข้อมูลมากที่สุดเพียงข้อเดียว

ลำดับ	รายการ	รายละเอียด/ตัวเลือก	หมายเหตุ
1	รหัสผู้เข้าร่วมวิจัย	[ID: ____]	กำหนดเฉพาะ เช่น P001, P002
2	วันที่เก็บข้อมูล	[___/___/___]	ว/ด/ป
3	เพศ	☐ ชาย ☐ หญิง	
4	อายุ	_______ ปี	ณ วันที่เก็บข้อมูล
5	ระดับการศึกษาสูงสุด	☐ ไม่ได้ศึกษา ☐ ประถม ☐ ม.ต้น ☐ ม.ปลาย ☐ อื่นๆ: _______	ข้อมูลจากเวชระเบียน
6	ระดับความบกพร่องทางสติปัญญา	☐ Mild ☐ Moderate ☐ ไม่ระบุ ☐ อื่นๆ: _______	ข้อมูลจากเวชระเบียน
7	คะแนน IQ ล่าสุด	_______ คะแนน	ข้อมูลจากเวชระเบียน
8	ส่วนสูง	_______ ซม.	
9	น้ำหนัก	_______ กก.	
10	BMI	_______ kg/m^2	น้ำหนัก(kg)/ส่วนสูง^2(m)
11	ความดันโลหิต	_______ mmHg	

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คณะกรรมการจริยธรรมการวิจัยในมนุษย์ สถาบันราชานุกูล
เอกสารจากผู้วิจัย Version 2 วันที่ 27 ต.ค. 2568
พิจารณาวันที่ 31 ตุลาคม 2568

Figure C1 Data recording form

ลำดับ	รายการ	รายละเอียด/ตัวเลือก	หมายเหตุ
12	อัตราการเต้นของหัวใจ	_______ bpm	
13	โรคร่วม	☐ ไม่มี ☐ มี (ระบุ): ________	ข้อมูลจากเวชระเบียน
14	ประวัติการใช้ยา	☐ ไม่มี ☐ มี (ระบุ): ________	ข้อมูลจากเวชระเบียน
15	การช่วยเหลือตนเอง	☐ ได้เอง ☐ ช่วยบางส่วน ☐ ต้องดูแลทั้งหมด	สัมภาษณ์ครู ผู้ปกครองหรือผู้ดูแล/ข้อมูลจากเวชระเบียน
16	การทำตามคำสั่ง	☐ สามารถทำตามคำสั่งง่าย ๆ 1–2 ขั้นตอนที่เกี่ยวข้องกับการทดสอบทางการเคลื่อนไหวและการรับรู้ เช่น การเดินตามคำสั่ง การก้าวเท้าตามจังหวะ หรือการตอบสนองต่อสัญญาณภาพ/เสียง ได้โดยไม่ต้องใช้การช่วยเหลือ ☐ ไม่สามารถทำตามคำสั่งดังกล่าวได้ หรือต้องใช้การช่วยเหลืออย่างมาก เช่น การชี้นำทางกายภาพ ภาพช่วย หรือแปลคำสั่งให้หลายครั้ง	สัมภาษณ์ครู ผู้ปกครองหรือผู้ดูแล/ข้อมูลจากเวชระเบียน
17	การรู้จักตัวเลข	☐ นับเลข 1-25 ได้อย่างถูกต้อง ☐ นับเลข <25 ☐ ไม่สามารถนับเลขได้เลย	ข้อมูลได้จากกิจกรรมประเมินเบื้องต้นโดยใช้บัตรตัวเลข และการสังเกตการตอบสนองในกิจกรรมการนับเลข

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Figure C1 (continued)

ลำดับ	รายการ	รายละเอียด/ตัวเลือก	หมายเหตุ
18	การแยกแยะสี	☐ แยกแยะได้ ≥ 7 สี (เช่น แดง เหลือง เขียว น้ำเงิน ม่วง ขาว ส้ม) ☐ แยกแยะได้ <7 สี ☐ ไม่สามารถแยกแยะสีได้เลย	ข้อมูลได้จากการสังเกตในกิจกรรมประเมินเบื้องต้นโดยใช้บัตรสีพื้นฐาน เพื่อดูความสามารถในการจำแนกและเปรียบเทียบสี
20	การทดสอบตาบอดสี	☐ เห็นตัวเลขได้ถูกต้อง ☐ เห็นตัวเลขผิด หรือไม่สามารถมองเห็นตัวเลขในแผ่นทดสอบได้เลย	ข้อมูลได้จากกิจกรรมประเมินเบื้องต้นโดยใช้ แบบทดสอบ Ishihara Color Vision Test
21	การรู้จักรูปทรง	☐ แยกรูปทรงพื้นฐานได้ (วงกลม, สามเหลี่ยม, สี่เหลี่ยม) ☐ ไม่สามารถแยกรูปทรงได้	ข้อมูลได้จากกิจกรรมประเมินเบื้องต้นโดยใช้บัตรหรือวัตถุรูปทรงต่างๆ เพื่อดูความสามารถในการจำแนกและจับคู่รูปทรง
22	การรู้จำตัวอักษร	☐ รู้จักตัวอักษร A–Z(หรือ ก–ฮ) ≥50% ☐ ไม่สามารถรู้จำตัวอักษรได้	ข้อมูลได้จากกิจกรรมประเมินเบื้องต้นโดยใช้บัตรตัวอักษร เพื่อสังเกตความสามารถในการจดจำตัวอักษร
23	ประวัติการออกกำลังกาย	☐ ไม่เคย ☐ <2 วัน/สัปดาห์ ☐ ≥3 วัน/สัปดาห์	สัมภาษณ์ครู ผู้ปกครองหรือผู้ดูแล
24	ประสบการณ์ NSE	☐ ไม่เคย ☐ เคย (ระบุ): ____________	สัมภาษณ์ครู ผู้ปกครองหรือผู้ดูแล

ผู้เก็บข้อมูล:

ลงชื่อ: .... วันที่: ..../.........../...........

ผู้ให้ข้อมูล (ถ้ามี):

ลงชื่อ: .... วันที่: ..../.........../...........

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Figure C1 (continued)

รับรองโดยคณะกรรมการจริยธรรมการวิจัยในมนุษย์
สถาบันราชานุกูล
รหัสโครงการวิจัย RI .IRB 012 / 2568-Exp
วันที่รับรอง 12 พฤศจิกายน 2568

แบบบันทึกผลการประเมิน Functional ability

รหัสผู้เข้าร่วมวิจัย: ____________________ วันที่ทดสอบ: _____/_____/________

คำชี้แจงการบันทึกข้อมูล

- **ความสามารถด้านการเดิน ทดสอบด้วย** 10-meter walk test (10MWT) ผู้เข้าร่วมการทดสอบเดินด้วยความเร็วที่สบาย(ปกติ) ระยะทาง 10 เมตรสำหรับจับเวลา โดยมี ช่วงเร่งความเร็ว 2 เมตรก่อนเริ่มจับเวลา และ ช่วงชะลอความเร็ว 2 เมตรหลังจบการจับเวลา การทดสอบนี้ทำทั้งหมด 3 ครั้ง และนำค่าความเร็วเฉลี่ยที่ได้จากทั้ง 3 ครั้งมาคำนวณเป็น**หน่วยเมตรต่อวินาที**
- **ความสามารถในการทรงตัวขณะเคลื่อนไหว ทดสอบโดย** Timed up and go test (TUGT) ผู้เข้าร่วมการทดสอบนั่งบนเก้าอี้มีพนักเท้ามือมาตรฐาน โดยให้หลังชิดพนักพิงเก้าอี้และวางเท้าแนบพื้นทั้งสองข้าง เมื่อได้ยินสัญญาณ "ไป" ผู้เข้าร่วมจะต้องลุกจากเก้าอี้ เดินไปข้างหน้าเป็นระยะทาง 3 เมตร อ้อมกรวยและหมุนตัวกลับ แล้วเดินกลับมานั่งบนเก้าอี้ในท่าเดิม โดยผู้ทดสอบจะจับเวลาตั้งแต่อาสาสมัครลุกขึ้นยืนจากเก้าอี้ และหยุดเวลาเมื่อผู้เข้าร่วมวางหลังชิดพนักพิงของเก้าอี้อีกครั้ง ทำการทดสอบ 3 ครั้งแล้วหาค่าเฉลี่ยเพื่อบันทึกผล
- **ความแข็งแรงของกล้ามเนื้อขา ทดสอบด้วย** Five times sit-to-stand test (FTSST) ผู้เข้าร่วมการทดสอบนั่งบนเก้าอี้มาตรฐาน โดยให้หลังชิดพนักพิงและวางเท้าราบกับพื้น ทั้งนี้ให้ผู้เข้าร่วมไขว้แขนไว้ที่หน้าอก เมื่อได้ยินสัญญาณ "ไป" ผู้เข้าร่วมจะต้องลุกขึ้นยืนให้สุด และนั่งกลับลงบนเก้าอี้ ทำทั้งหมด 5 ครั้งให้เร็วที่สุด โดยผู้ทดสอบจะจับเวลาตั้งแต่เริ่มต้นจนกระทั่งทำครบ 5 ครั้ง ผู้เข้าร่วมจะต้องเหยียดเข่าให้สุดขณะยืนขึ้น และนั่งให้เต็มก้นสัมผัสกับเบาะเก้าอี้ทุกครั้ง ทำการทดสอบ 3 ครั้งแล้วหาค่าเฉลี่ยเพื่อบันทึกผล
- **ความทนทาน ทดสอบโดย** 6-minute walk test (6MWT) ผู้เข้าร่วมการทดสอบจะได้รับคำแนะนำให้เดินไปกลับตามทางเดินความยาว 30 เมตร เป็นเวลา 6 นาที โดยอนุญาตให้ชะลอความเร็วหรือหยุดพักได้หากจำเป็น แต่จะได้รับการกระตุ้นให้กลับมาเดินต่อเมื่อรู้สึกพร้อม หลังจากครบเวลา 6 นาที จะมีการบันทึกระยะทางรวมที่เดินได้ (หน่วยเป็นเมตร)

การทดสอบ	☐ Baseline ☐ After four weeks exercise			**ค่าเฉลี่ย**
	ครั้งที่ 1	**ครั้งที่ 2**	**ครั้งที่ 3**	
10MWT				(s)
Speed	V=S/T Set; S=10m			V= ......m/s
TUG				(s)
FTSST				(s)
6MWT				(m)

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Figure C2 Functional ability assessment recording form

รับรองโดยคณะกรรมการจริยธรรมการวิจัยในมนุษย์
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รหัสโครงการวิจัย RI .IRB 012 / 2568 - Exp
วันที่รับรอง 12 พฤศจิกายน 2568

แบบบันทึกผลการประเมิน Cognitive function

รหัสผู้เข้าร่วมวิจัย: ____________________ วันที่ทดสอบ: ____/____/________

คำชี้แจงการบันทึกข้อมูล

- **การวัดความเร็วในการประมวลผลของสมอง: เวลาปฏิกิริยาอย่างง่าย (Simple reaction time test)** ผู้เข้าร่วมจะจ้องไปที่หน้าจอคอมพิวเตอร์ และตอบสนองโดยเร็วที่สุดเมื่อเห็นวงกลมสีแดงปรากฏขึ้นตรงกลางหน้าจอ โดยมีคำแนะนำให้กดปุ่ม "/" บนแป้นพิมพ์ด้วยนิ้วชี้ทุกครั้งที่สิ่งเร้าปรากฏ การทดสอบประกอบด้วยการแสดงสิ่งเร้าจำนวน 20 ครั้ง ผลการทดสอบจะถูกวิเคราะห์จากค่าเฉลี่ยของเวลาตอบสนองที่ถูกต้อง (หน่วยเป็นมิลลิวินาที) และอัตราความแม่นยำในการตอบสนอง (หน่วยเป็นเปอร์เซ็นต์)
- **การวัดความเร็วในการประมวลผลของสมองและประสิทธิภาพในการตัดสินใจ: เวลาปฏิกิริยาแบบตัวเลือก (Choice reaction time test)** ผู้เข้าร่วมจะจ้องไปที่หน้าจอคอมพิวเตอร์ และตอบสนองต่อสิ่งเร้าสีต่างๆ ที่ปรากฏแบบสุ่มบนหน้าจอคอมพิวเตอร์ ได้แก่: ใช้นิ้วชี้ของมือซ้ายกดที่ ปุ่ม"Z"เมื่อลูกบอลสีแดงปรากฏ ใช้นิ้วชี้ของมือขวากดที่ ปุ่ม"/"เมื่อลูกบอลน้ำเงินปรากฏ และไม่กดปุ่มใดๆ เมื่อลูกบอลสีเหลืองปรากฏ การทดสอบประกอบด้วยสิ่งเร้าแบบสุ่มจำนวน 60 ครั้ง โดยผู้เข้าร่วมต้องตอบสนองอย่างถูกต้องและรวดเร็วที่สุดเท่าที่จะทำได้ ผลการทดสอบจะวิเคราะห์จากค่าเฉลี่ยของเวลาตอบสนองที่ถูกต้อง (มิลลิวินาที) และอัตราความแม่นยำของการตอบสนอง (หน่วยเป็นเปอร์เซ็นต์)
- **การวัดความสนใจ และความเร็วในการประมวลผลของสมอง:** Trail making test Part A ผู้เข้าร่วมการทดสอบต้องใช้เมาส์คลิกที่วงกลมที่มีหมายเลขซึ่งแสดงบนหน้าจอเรียงตามลำดับจากเลข 1 ถึง 25 ให้เร็วและแม่นยำที่สุด การทดสอบจะเริ่มต้นด้วยหน้าจอเตรียมความพร้อม และเมื่อเริ่มต้นแล้ว ผู้เข้าร่วมจะต้องค้นหาและคลิกที่หมายเลข 1 จากนั้นจึงคลิกหมายเลข 2, 3, 4 ไปเรื่อย ๆ ตามลำดับ จนถึงหมายเลข 25 วงกลมที่ถูกคลิกถูกต้องจะมีเส้นสีแดงเชื่อมต่อกันเป็นเส้นต่อเนื่อง หากคลิกผิดหมายเลข เส้นจะไม่ปรากฏ แสดงว่าเกิดข้อผิดพลาด ผลการทดสอบจะประเมินจาก ระยะเวลาในการทำแบบทดสอบจนเสร็จ (หน่วยเป็นวินาที) และจำนวนครั้งที่ผิดพลาด

แบบทดสอบ (Cognitive tests)	☐ Baseline ☐ After four weeks exercise	
	ผลการทดสอบความสามารถทางสมอง	
เวลาปฏิกิริยาอย่างง่าย (Simple reaction time test)	ความเร็วในการตอบสนอง (Average reaction times of correct responses)	มิลลิวินาที (msec)
	ความสามารถในการตอบสนองอย่างถูกต้อง (Accuracy of responses)	% (Percentage)
เวลาปฏิกิริยาแบบตัวเลือก (Choice reaction time test)	ความเร็วในการตอบสนอง (Average reaction times of correct responses)	มิลลิวินาที (msec)
	ความสามารถในการตอบสนองอย่างถูกต้อง (Accuracy of responses)	% (Percentage)
เทรลเมคคิ่ง (Trail making test Part A)	เวลาที่ใช้ในการทดสอบ (Completion time)	วินาที (Seconds)
	จำนวนครั้งที่ผิดพลาด (Number of Errors)	ครั้ง

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Figure C3 Cognitive function assessment recording form

แบบบันทึกข้อมูลการออกกำลังกายรายบุคคล

ด้วยเครื่อง Illuminated Nine-Square Dance Pad (INSP)

รหัสผู้เข้าร่วมวิจัย: ____________________

คำชี้แจงการบันทึกข้อมูล

ใช้สำหรับบันทึกข้อมูลการออกกำลังกายของผู้เข้าร่วมรายบุคคล โดยใช้เครื่อง Illuminated Nine-Square Dance Pad (INSP)

นักกายภาพบำบัด เป็นผู้กรอกแบบฟอร์มนี้ทุกครั้งหลังการฝึก เพื่อใช้ประกอบการวิเคราะห์ผลลัพธ์ของโปรแกรมการออกกำลังกาย และความเหมาะสมของการฝึกในแต่ละบุคคล

ครั้งที่/วันที่ฝึก	อัตราการเต้นของหัวใจก่อนฝึก (HRrest)	อัตราการเต้นของหัวใจระหว่างฝึก (HRmax)	สรุปผลการฝึก (Training Summary)			
			Final Score (คะแนนรวม)	Patterns Completed (รูปแบบที่ทำได้)	Progress (ความคืบหน้า)	Average reaction time (ค่าเฉลี่ยเวลาตอบสนอง)
ครั้งที่1 ____/____/________	____ bpm	____ bpm			%	msec
ครั้งที่2 ____/____/________	____ bpm	____ bpm			%	msec
ครั้งที่3 ____/____/________	____ bpm	____ bpm			%	msec
ครั้งที่4 ____/____/________	____ bpm	____ bpm			%	msec
ครั้งที่5 ____/____/________	____ bpm	____ bpm			%	msec
ครั้งที่6 ____/____/________	____ bpm	____ bpm			%	msec
ครั้งที่7 ____/____/________	____ bpm	____ bpm			%	msec
ครั้งที่8 ____/____/________	____ bpm	____ bpm			%	msec

Figure C4 INSP exercise training data recording form

รับรองโดยคณะกรรมการจริยธรรมการวิจัยในมนุษย์
สถาบันราชานุกูล
รหัสโครงการวิจัย RI .IRB 012 / 2568_Exp
วันที่รับรอง 12 พฤศจิกายน 2568

แบบบันทึกข้อมูลการออกกำลังกายรายบุคคล

ด้วยการออกกำลังกายภาพบำบัดดั้งเดิม

รหัสผู้เข้าร่วมวิจัย: ____________________

คำชี้แจงการบันทึกข้อมูล

ใช้สำหรับบันทึกข้อมูลการออกกำลังกายของผู้เข้าร่วมรายบุคคล ด้วยการกายภาพบำบัดทั่วไป **นักกายภาพบำบัด** เป็นผู้กรอกแบบฟอร์มนี้ทุกครั้งหลังการฝึก เพื่อใช้ประกอบการวิเคราะห์ผลลัพธ์ของโปรแกรมการออกกำลังกาย และความเหมาะสมของการฝึกในแต่ละบุคคล

ครั้งที่/วันที่ฝึก	อัตราการเต้นของหัวใจก่อนฝึก (HRrest)	อัตราการเต้นของหัวใจระหว่างฝึก (HRmax)	หมายเหตุ
ครั้งที่1 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	
ครั้งที่2 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	
ครั้งที่3 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	
ครั้งที่4 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	
ครั้งที่5 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	
ครั้งที่6 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	
ครั้งที่7 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	
ครั้งที่8 วันที่ฝึก: ____/____/________	________ bpm	________ bpm	

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เอกสารจากผู้วิจัย Version 2 วันที่ 27 ต.ค. 2568
พิจารณาวันที่ 31 ตุลาคม 2568

Figure C5 Conventional physical therapy exercise data recording form

APPENDIX D

PHASE 1 DEVICE TESTING ASSESSMENT FORM FOR THE ILLUMINATED NINE-SQUARE DANCE PAD (INSP)

แบบประเมินการทดสอบแผ่นเต้นตารางเก้าช่องที่มีไฟเรืองแสงนำทาง

(Illuminated Nine-Square Dance Pad: INSP)

รหัสอาสาสมัคร	....	**อายุ**	....
เพศ	....	**วันที่ทดสอบ**	....

วัตถุประสงค์ของการประเมิน

แบบประเมินนี้ใช้เพื่อประเมินความเป็นไปได้และความปลอดภัยของแผ่นเต้นตารางเก้าช่องที่มีไฟเรืองแสงนำทาง (INSP) ก่อนนำไปใช้จริงในการวิจัยหลัก โดยครอบคลุมด้านการเข้าใจคำสั่ง การทำตามขั้นตอนการก้าว ความแม่นยำของระบบ ตรวจจับแรงกด ความปลอดภัยระหว่างใช้งาน และความคิดเห็นจากผู้ปกครองหรือผู้ดูแล

ส่วนที่ 1 การเข้าใจคำสั่งและความสามารถในการปฏิบัติตามขั้นตอนการก้าว

คำชี้แจง: ให้ผู้ประเมินสังเกตว่าอาสาสมัครสามารถเข้าใจคำอธิบาย ทำตามการสาธิต และก้าวได้ถูกต้องตามช่องที่กำหนดหรือไม่

1.1 การเข้าใจและการปฏิบัติตามคำสั่ง

รายการประเมิน	ได้	ไม่ได้	หมายเหตุ
1. อาสาสมัครเข้าใจคำอธิบายด้วยวาจา	☐	☐	
2. อาสาสมัครสามารถทำตามการสาธิตได้	☐	☐	
3. อาสาสมัครสามารถเริ่มก้าวได้หลังได้รับคำสั่ง	☐	☐	
4. อาสาสมัครก้าวลงช่องที่กำหนดได้ถูกต้อง	☐	☐	
5. อาสาสมัครสามารถทำกิจกรรมได้โดยไม่ต้องช่วยพยุงตลอดเวลา	☐	☐	

1.2 จำนวนรอบของการอธิบายหรือสาธิตก่อนที่อาสาสมัครจะทำได้ถูกต้อง

☐ 1 รอบ ☐ 2 รอบ ☐ มากกว่า 2 รอบ

หมายเหตุ: ....

1.3 ความถูกต้องของการก้าวในแต่ละรอบ

จำนวนรอบทั้งหมด	....
จำนวนรอบที่ทำได้ถูกต้อง	....
คิดเป็นร้อยละ (%)	....
ผลการประเมิน	☐ ผ่าน ☐ ไม่ผ่าน

เกณฑ์ผ่าน: อาสาสมัครสามารถทำตามคำสั่งการก้าวได้ถูกต้องอย่างน้อย 80% ของรอบทั้งหมด

ส่วนที่ 2 ความแม่นยำของระบบตรวจจับแรงกดของเครื่อง INSP

คำชี้แจง: ให้บันทึกว่าระบบสามารถตรวจจับแรงกดเท้าและแสดงสัญญาณไฟได้ถูกต้องหรือไม่ในแต่ละรอบ

รอบที่	ตรวจจับแรงกดได้ถูกต้อง	ไฟแสดงผลถูกต้อง	พบความผิดพลาด	หมายเหตุ
1	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	
2	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	
3	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	
4	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	
5	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	☐ ใช่ ☐ ไม่ใช่	

สรุปผล

จำนวนรอบทั้งหมด	....
จำนวนรอบที่ตรวจจับได้ถูกต้อง	....
ความแม่นยำของระบบตรวจจับแรงกด (%)	....
ผลการประเมิน	☐ ผ่าน ☐ ไม่ผ่าน

เกณฑ์ผ่าน: ระบบตรวจจับแรงกดของเครื่องมีความแม่นยำไม่น้อยกว่า 90%

ส่วนที่ 3 ความปลอดภัยขณะใช้งานเครื่อง

คำชี้แจง: ให้ผู้ประเมินสังเกตอาสาสมัครตลอดช่วงการทดสอบว่ามีเหตุการณ์ไม่พึงประสงค์เกิดขึ้นหรือไม่

รายการด้านความปลอดภัย	มี	ไม่มี	หมายเหตุ
1. ลื่นขณะก้าว	☐	☐	
2. เสียการทรงตัว	☐	☐	
3. หกล้ม	☐	☐	
4. มีอาการบาดเจ็บหรือปวดระหว่างทดสอบ	☐	☐	
5. ต้องหยุดการทดสอบทันที	☐	☐	

สรุปความปลอดภัยโดยรวม: ☐ ปลอดภัย ☐ ไม่ปลอดภัย

เกณฑ์ผ่าน: ไม่มีการลื่น หกล้ม หรือเหตุการณ์ไม่พึงประสงค์ระหว่างการทดสอบ

ส่วนที่ 4 แบบประเมินความคิดเห็นของผู้ปกครองหรือผู้ดูแล

คำชี้แจง: โปรดทำเครื่องหมาย ✓ ลงในระดับความคิดเห็นที่ตรงกับความเห็นของท่านมากที่สุด

ระดับคะแนน: 1 = ไม่เห็นด้วยอย่างยิ่ง 2 = ไม่เห็นด้วย 3 = ไม่แน่ใจ 4 = เห็นด้วย 5 = เห็นด้วยอย่างยิ่ง

ข้อความประเมิน	1	2	3	4	5
1. เครื่องนี้มีความเหมาะสมสำหรับผู้ที่มีภาวะบกพร่องทางสติปัญญา	☐	☐	☐	☐	☐
2. เครื่องนี้ใช้งานได้ง่าย	☐	☐	☐	☐	☐
3. สัญญาณไฟช่วยให้อาสาสมัครมองเห็นตำแหน่งการก้าวได้ง่ายขึ้น	☐	☐	☐	☐	☐
4. เครื่องนี้มีความปลอดภัยขณะใช้งาน	☐	☐	☐	☐	☐
5. เครื่องนี้ช่วยเพิ่มความสนใจและการมีส่วนร่วมระหว่างฝึก	☐	☐	☐	☐	☐

ข้อเสนอแนะเพิ่มเติมจากผู้ปกครองหรือผู้ดูแล

....

....

ผลการประเมินโดยรวม: ☐ **ผ่าน** ☐ **ไม่ผ่าน**

เกณฑ์ผ่าน: ผู้ปกครองหรือผู้ดูแลประเมินว่าเครื่องเหมาะสม ใช้งานง่าย และปลอดภัย

ส่วนที่ 5 ข้อเสนอแนะเพื่อการปรับปรุงเครื่องก่อนใช้จริง

คำชี้แจง: ให้ผู้ประเมินบันทึกว่ามีส่วนใดของเครื่องหรือขั้นตอนที่ควรปรับปรุงก่อนเริ่มการวิจัยหลัก

รายการที่ควรพิจารณา	ควรปรับปรุง	ไม่ต้องปรับปรุง	ข้อเสนอแนะ
1. โปรแกรมไฟ	☐	☐	
2. ความไวของแผ่นรองรับแรงกด	☐	☐	
3. วิธีการอธิบายหรือสาธิต	☐	☐	
4. ความเร็วหรือระดับความยากของการฝึก	☐	☐	
5. อื่น ๆ	☐	☐	

ส่วนที่ 6 สรุปผลการทดสอบความเป็นไปได้ของเครื่อง INSP

เกณฑ์ประเมิน	ผ่าน	ไม่ผ่าน
1. อาสาสมัครทำตามคำสั่งการก้าวได้ถูกต้องอย่างน้อย 80%	☐	☐
2. ระบบตรวจจับแรงกดมีความแม่นยำไม่น้อยกว่า 90%	☐	☐
3. ไม่มีเหตุการณ์ไม่พึงประสงค์หรือการหกล้มระหว่างทดสอบ	☐	☐
4. ผู้ปกครองหรือผู้ดูแลประเมินว่าเครื่องเหมาะสม ใช้งานง่ายและปลอดภัย	☐	☐

ผลการพิจารณาโดยรวม

☐ เหมาะสมสำหรับนำไปใช้ในการวิจัยหลัก ☐ เหมาะสมหลังปรับปรุงเล็กน้อย

☐ ยังไม่เหมาะสมสำหรับนำไปใช้ในการวิจัยหลัก

สรุปข้อคิดเห็นเพิ่มเติม

....

....

ลายมือชื่อผู้ประเมิน:	วันที่: .... / .... / ....
ลายมือชื่อผู้บันทึกข้อมูล:	ลายมือชื่อผู้ปกครอง/ผู้ดูแล: ....

APPENDIX E

STEPS FOR USING THE ILLUMINATED NINE-SQUARE DANCE PAD (INSP)

ขั้นตอนการใช้งานโปรแกรม Illuminated nine-square dance pad (INSP)

1. หน้าจอเริ่มต้น (Start Screen)

- **เริ่มโปรแกรมและหน้าต้อนรับ**: แสดงโลโก้โปรแกรมและข้อความต้อนรับ
- **ปุ่มเมนู**: แสดงตัวเลือก:
    - **เริ่ม (Start)**: เริ่มเข้าสู่โปรแกรม
    - **ออกจากโปรแกรม (Exit)**: ปิดโปรแกรม

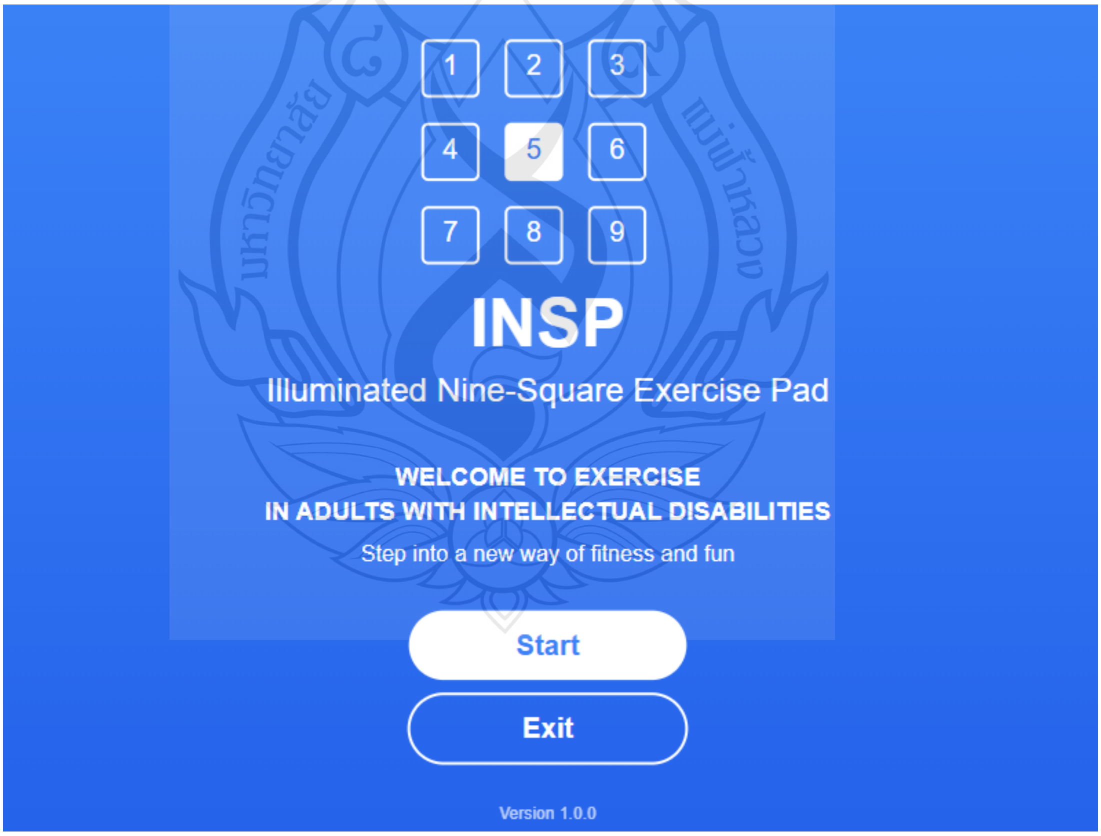

Figure E1 Start screen of the INSP program

2. เริ่ม (Start):

- **การจัดการโปรไฟล์ผู้ใช้:**
    - ผู้ใช้ใหม่
        - สร้างโปรไฟล์ใหม่
            - ใส่ชื่อ/ID
            - อายุ
            - เพศ
    - ผู้ใช้เก่า
        - เข้าสู่ระบบด้วยรหัสผู้ใช้หรือเลือกโปรไฟล์

- มีปุ่ม "ย้อนกลับ (Back to Menu)"

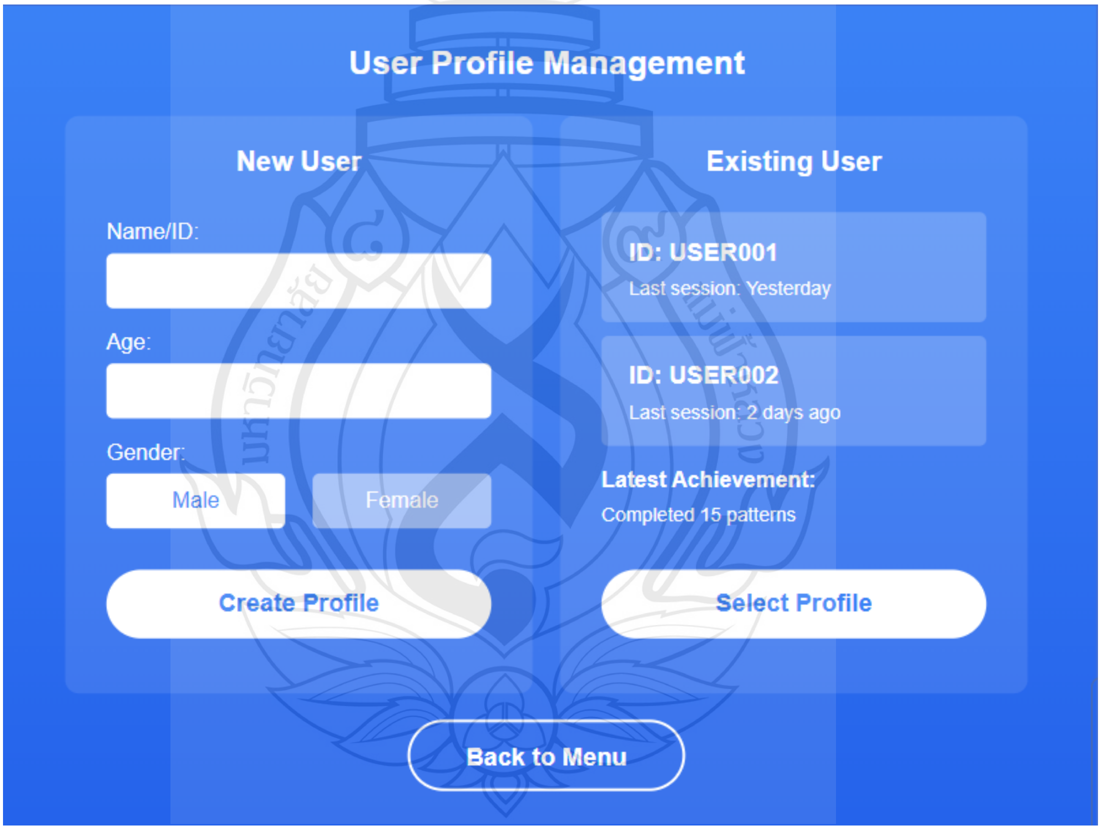

Figure E2 User profile management screen of the INSP program

3. **เมนูหลัก (Main menu):**

การเลือกโหมด

- **โหมดฝึกซ้อม (Testing):**
  - แบบตามลำดับขั้น (Ordinary mode)
- **โหมดฝึกฝน (Training):**
  - แบบตามลำดับขั้น (Ordinary mode)
  - แบบสุ่ม (Random mode)
  - แบบตามลำดับขั้นเลขคู่ (Even number mode)
  - แบบตามลำดับขั้นเลขคี่ (Odd number mode)
- มีปุ่ม "ย้อนกลับ (Back to Menu)"

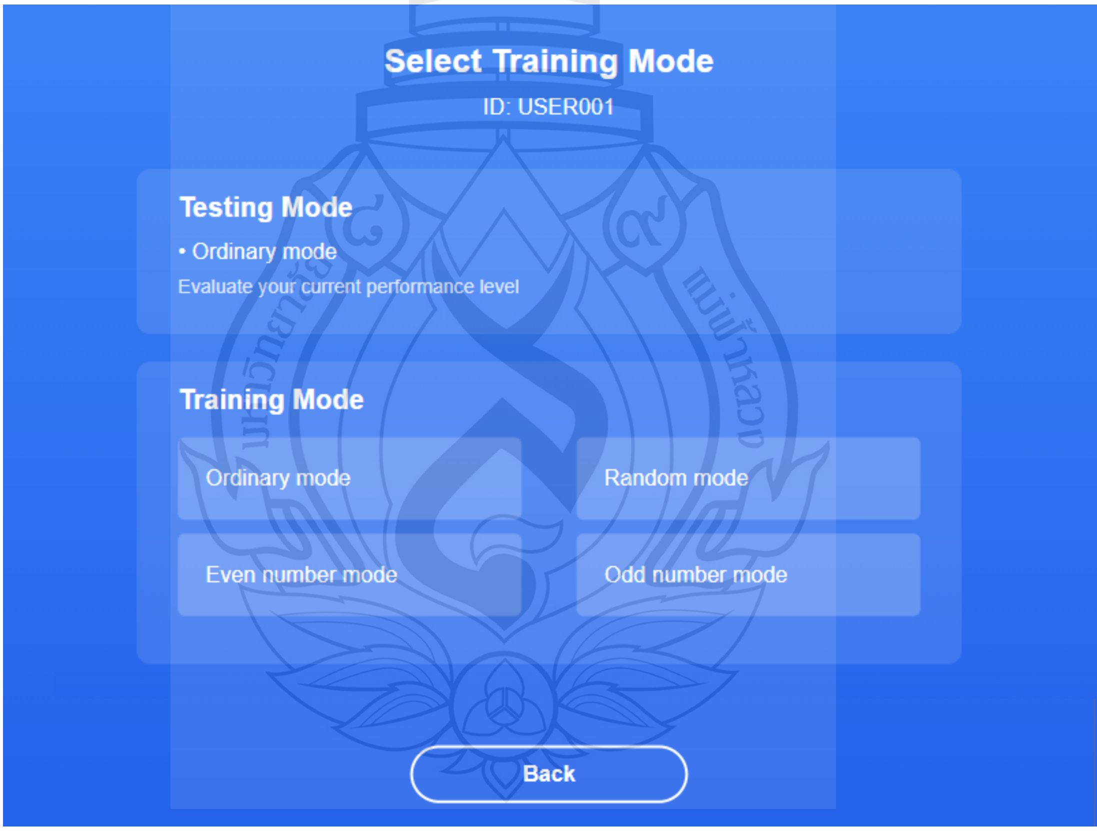

Figure E3 Mode selection screen of the INSP program

4. **หน้าจอการฝึก:**

- **แสดงตาราง 9 ช่อง:**
    - ช่องที่มีไฟแสดงถึงจุดที่ต้องก้าว
    - แต่ละช่องมีหมายเลขหรือสีเพื่อช่วยระบุตำแหน่ง
    - ช่องที่แสดงไฟจะดับลง เมื่อก้าวไปที่ช่องนั้นถูกต้อง นับเป็น 1 คะแนน
- **ตัวจับเวลา** (Timer):
    - แสดงระยะเวลาการฝึก (45:00นาที)
- **คะแนน** (Score):
    - คะแนนเพิ่มขึ้นเมื่อก้าวถูกต้อง
- **คำแนะนำ** (Instructions):
    - เช่น แสดงทิศทางการก้าว, บอกตัวเลข, รูปแบบการก้าว

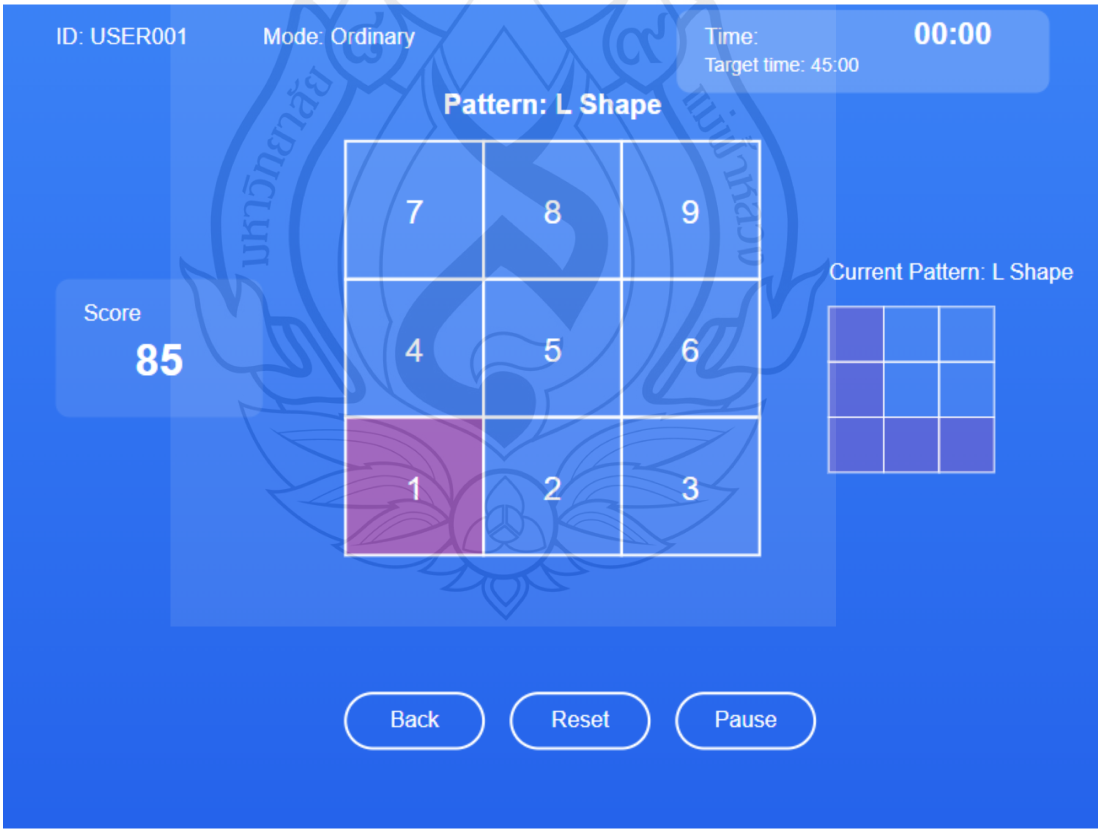

Figure E4 Training screen of the INSP program

5. การสิ้นสุดการฝึก:

สรุปการฝึก

- แสดงคะแนนรวม(Score)
- แสดงรูปแบบที่ทำสำเร็จ
- ปุ่มให้เลือก:
    - **เล่นอีกครั้ง (Play Again)**
    - **พิมพ์ข้อมูล:** พิมพ์ข้อมูลสรุปการฝึกในแต่ละครั้ง
    - **กลับสู่หน้าหลัก (Back to Menu)**

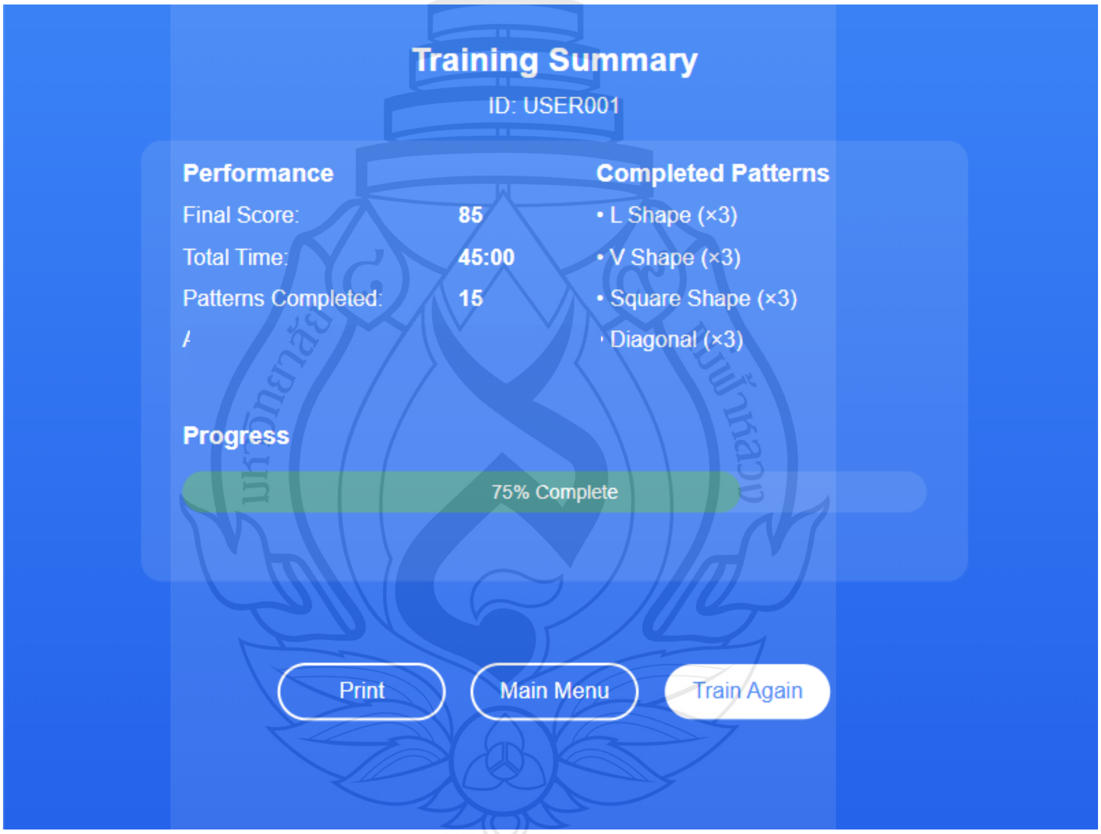

Figure E5 Summary screen of the INSP program

6. การออกจากโปรแกรม (Exit)

1. แสดงข้อความยืนยัน:
    - "คุณต้องการออกจากโปรแกรมหรือไม่?"
    - ปุ่ม **ยืนยัน** (Yes) หรือ **ยกเลิก** (No)

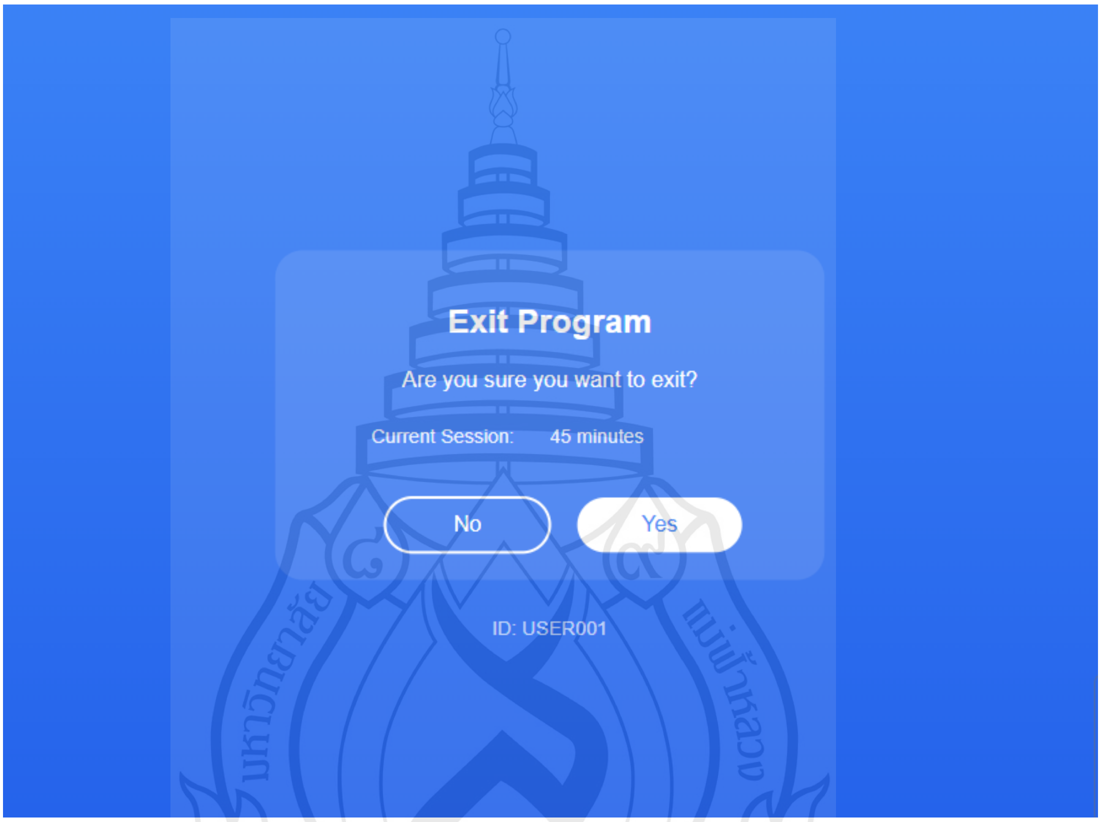

Figure E6 Exit screen of the INSP program

APPENDIX F

CONCEPTUAL FRAMEWORK OF THE STUDY

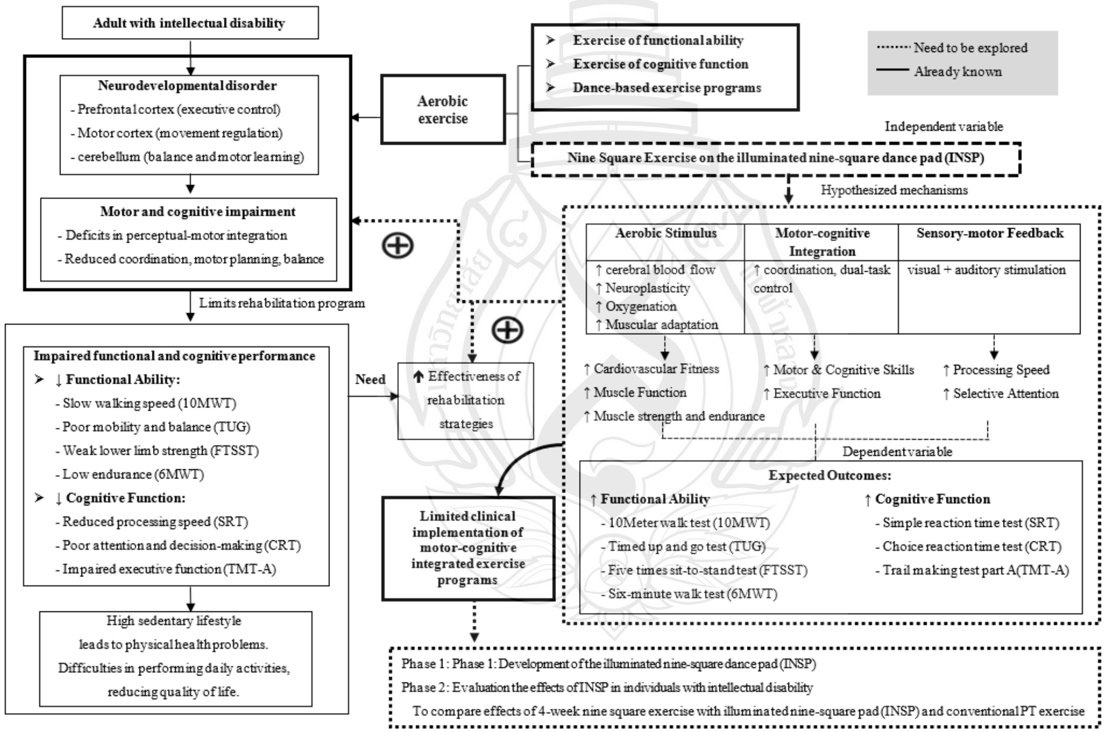

Figure F1 Conceptual framework: Effect of nine square exercise on functional ability and cognitive function in adults with intellectual disability

APPENDIX G

RECRUITMENT AND PARTICIPANT MATERIALS

Figure G1 Recruitment poster

รับรองโดยคณะกรรมการจริยธรรมการวิจัยในมนุษย์
สถาบันราชานุกูล
รหัสโครงการวิจัย RI : IRB 012 / 2568_Exp
วันที่รับรอง 12 พฤศจิกายน 2568

Version 1.0 วันที่ 7 ตุลาคม 2568

บัตรประจำตัวอาสาสมัคร

โครงการวิจัย: ผลของการออกกำลังกายตารางเก้าช่อง (Nine Square Exercise) ต่อความสามารถทางกายและความสามารถด้านสติปัญญาในผู้ใหญ่ที่มีความบกพร่องทางสติปัญญา

รหัส

อายุ

เพศ

สถานที่: งานกายภาพบำบัด สถาบันราชานุกูล

โทร.085-0655149

การนัดหมาย

ครั้งที่	ว/ด/ป ที่นัด	มา/ไม่มา
ทดสอบก่อน		
1		
2		
3		
4		
5		
6		
7		
8		
ทดสอบหลัง		

หมายเหตุ: ให้นำบัตรนัดมาด้วยทุกครั้ง

คณะกรรมการจริยธรรมการวิจัยในมนุษย์ สถาบันราชานุกูล
เอกสารจากผู้วิจัย Version 1 วันที่ 7 ต.ค. 2568
พิจารณาวันที่ 21 ตุลาคม 2568

Figure G2 Participant ID card

Figure G3 Participant handbook (cover)

Figure G4 Participant handbook (sample pages 1,6)

Figure G5 Participant handbook (sample pages 5, 2)

Figure G6 Participant handbook (sample pages 3, 4)

CURRICULUM VITAE

NAME	Juthamart Kohkaew
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WORK EXPERIENCE	
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