Title: Defining the Minimum Time Threshold for Natural Functional Development of Motor and Cognitive Skills: A Pilot Clinical Trial of Temporal Constraints in Hjelm's Function-oriented Intervention Method for Children with Specific Learning Disorder

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ABSTRACT

Introduction: Children with specific learning disorders, having delay in brain development, need interventions developing brain functions. Hjelm's function-oriented approach emphasizes sufficient time between sessions in natural functional development of brain functions. This study aimed to investigate whether a structurally restricted timeframe is sufficient to elicit developmental changes, thereby defining a minimum effective threshold for Hjelm's function-oriented intervention.

Methods: Nineteen children aged 7-12 years with specific learning disorders participated in 16 weeks-intervention, one 20-minutes-session weekly. The outcome measures included Behavior Rating Inventory of Executive Function, Continuous Performance Test, Wechsler Memory Scale, Bruininks-Oseretsky Test of Motor Proficiency and Clinical Observation of Motor and Postural Skills. Repeated measure ANOVA was used to analyze differences between the groups and paired t-tests to compare pre-and post-values for both groups separately.

Results: The intervention showed no significant differences between the groups. The intervention group showed significant improvements in gross motor skills, regression in some variables of motor skills and no changes in the cognitive skills. The control group showed significant improvements in postural motor skills. The control group demonstrated within-group improvements, particularly in total motor scores ($dz = -1.49$, 95% CI [-2.33, -0.63]), exceeding the changes in the intervention group.

Conclusion: The applied timeframe falls below the minimum effective threshold required to engage the central nervous system and the natural functional development productively.

This study shows the importance of time in natural functional development, and a restricted timeframe is not sufficient to elicit developmental changes, which should be considered when using Hjelm's function-oriented intervention.

Keywords: Hjelm's function-oriented intervention, Functional brain development, Minimum Time Threshold, Motor and postural skills, Cognition, Time factor

Highlights

- Importance of passage of time in natural functional development.
- Sufficient time between intervention sessions for natural functional development.
- The result complies with the intervention guidelines of the Hjelm Approach
- Timeframe should be considered when using Hjelm's function-oriented intervention.

Plain Language Summary

Children with Specific Learning Disorder (SLD) face challenges in personal, academic, occupational, and social functioning, with development in cognitive, language, social, and motor domains affected, which impact health, well-being, and coping skills across the lifespan. Interventions focusing on brain function development can facilitate child development. Hjelm's function-oriented interventions promote overall developmental patterns, encouraging functional development naturally through self-propelled, non-instructed movement. Incidental spontaneous actions, as reflexes and CNS reactions in motor development, must be gradually integrated and restrained to avoid interfering with voluntary movements.

Since many studies have overlooked the role of time in developmental changes, this study examined the result of using a restricted timeframe when applying shorter intervals between intervention sessions than typically emphasized in the Hjelm Approach, to increase understanding of the importance of time in natural functional development. With such a deeper insight it may be possible to optimize the society's use of Hjelm's function-oriented interventions, for the benefit of the individual's needs.

Results from the intervention group and the control group showed that the restricted timeframe in the intervention program was evidently insufficient to allow neurodevelopmental processes in natural functional development. This is in line with Hjelm's view that neglecting the time factor in natural functional development may lead to stagnation or even regression. The findings of this study highlight that the time factor is crucial in Hjelm's function-oriented interventions for promoting natural functional development in children with SLD or in persons in other target groups.

Introduction

Prevalence of developmental disorders is reported in different countries. For example, studies show that about 4.8% of primary school children in the UK, 15.4% of children aged 3-17 years in the US, 3.25% of Taiwanese children and 2.5% of Korean children have developmental disorders (Rah, Hong, & Yoon, 2020). In Iran, various statistics have reported a prevalence of 4.58-7.7% (Zare & Ganji, 2014). Attention-Deficit/Hyperactivity Disorder (ADHD), autism spectrum disorder and Specific Learning Disorder (SLD) can be mentioned among these disorders. Problems in personal, academic, occupational and social functioning are among the symptoms of persons with these disorders, which are caused by the delay in brain development during the early years of development (American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders Edition, 2013). Depending on the type of disorder, the occurrence of symptoms is more visible in a certain area. In children with SLD, symptoms of developmental disorders appear in the early years of development and manifest as learning difficulties during school years. In these children, development in all cognitive, language, social and motor areas is affected (American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders Edition, 2013).

Development and its four main domains, language, cognitive, social–emotional–behavioral, and motor-physical domains are the contributing factor in health, well-being and coping skills through life span. It is a strong predictor of adult health and productivity. So, dealing with developmental issues can be regarded as an investment in health conditions from a long-term perspective (Hertzman & Power, 2004). Regarding this, interventions which have emphasized brain function can be helpful to facilitate child development; because acquired complex skills are the production of changed neural basis (Johnson, 2001).

Several therapeutic interventions attempt to compensate for delayed development in SLD. Most of these interventions, however, affect a specific domain of development. For example, educational and cognitive approaches try to strengthen cognition, the motor control approaches try to strengthen motor skills, and the perceptual-motor approaches focus on strengthening perception. The concept of development includes all linguistic, cognitive, motor and emotional-social domains and in the development of the central nervous system (CNS), all these areas are interrelated. For example, research shows that motor development can facilitate processes of learning and development in a child, and motor behavior can be regarded as a connector between the three apparently different domains (Karen E. Adolph & Robinson, 2015). Therefore, it may be more effective to consider interventions that promote the overall pattern of the domains of development.

One intervention that may promote the overall development in all those domains is found among Hjelm's Health- and Development promoting Function-oriented interventions (Hjelm's HDF interventions) developed by Lasse Hjelm, (1924-2010) in Sweden. The interventions include a function-oriented action-based program for the promotion of functional development naturally in a self-propelled way through non-instructed movement development (Svanström, 2024). The program focuses on the overall development of fundamental functions in the body and the CNS of the client, including neuromuscular, motor, psychomotor, perceptual, cognitive and emotional areas (Elin Svanström, 2016). Hjelm established his intervention programs in 1976. The programs are derived from Hjelm's interdisciplinary function-oriented approach for the promotion of natural functional development (the Hjelm Approach), where the importance of the individual's own spontaneous actions constitutes the primary influence in that approach and in Hjelm's overall way of working (Hjelm, 2005). The Hjelm Approach is based on human's functional overall development and on Hjelm's perspective on resuming an individual's natural overall functional development (Hjelm, 2005; Svanström, 2024). One of the intervention tools, used in Hjelm's HDF interventions, is Hjelm's Function-oriented acoustic Melody signal Tool (FMT) method (Hjelm's FMT method), a non-verbal method consisting of recurring melody signals on an acoustic piano as a mean while the individual acts in relation to specially adapted drums and cymbals (Hjelm, 2005).

Lasse Hjelm (1924-2010), originally a music teacher, was invited by the rehabilitation center Folke Bernadottehemmet (FBh) at Uppsala University Hospital in Uppsala in Sweden with the purpose to try developing a new way of working towards certain target groups (Ray, 1998). Hjelm studied children's development from several scientific disciplines, such as children's motor, psychomotor, perceptual and cognitive development, which *"he then combined with his perspective on resuming an individual's natural functional development and formed it all into an interdisciplinary function-oriented approach that became the basis of Hjelm's FMT method as an intervention tool that was established in 1976"* (Svanström, 2024, p 9). Until he left the center in 1989, in connection with his retirement, he had expanded his work towards various disabilities (Hejlm, 2005). In 1987 he established a private educational center to train future function-oriented development specialist, which has been continued till now by the current head director, Elin Svanström in Uppsala. Nowadays the center is called Hjelm University, working in collaboration with Hjelm Institute for Natural Functional Development with the FMT Method, in Uppsala, which is providing research and professional training and education in Hjelm's HDF interventions and in the Hjelm Approach. In 2022, certain terms were replaced with new ones, to increase the clarity of the main field (Svanström, 2024).

Hjelm emphasizes both incidental and goal directed spontaneous actions in the individual, which has been issued by Adolph & Robinson (Karen E. Adolph & Robinson, 2015). They addressed that incidental actions and consequential functions regarding the myriad forms of spontaneous behavior are expressed in fetuses, infants, and young children while awake and asleep. Although incidental actions are not intentionally goal directed, it can still serve crucial functions in the process of development. In other words, these incidental spontaneous actions are the reflexes and reactions of the CNS in motor development, which must be integrated and restrained gradually over time so that they do not interfere with voluntary movements at an older age (Karen E. Adolph & Robinson, 2015). However, in neurodevelopmental disorders, such as learning disorders, this growth flow is damaged. As a result, these children have problems in performing voluntary activities in various areas of life.

BL4 Previous studies emphasize the positive outcomes of Hjelm's FMT method. Sundkvist-Stensman and Hjelm (1998) investigated the effect of two years of intervention with Hjelm's FMT method on 12 hospitalized people with schizophrenia. The results showed improvement in concentration, motor skills and sense of harmony, increased Global Functional Scale for Psychological, Social and Occupational Abilities (GAF score) and quality of life. In terms of activities of daily living functions, the ability to contact staff and other patients was mainly improved (Sundkvist-Stensman & Hjelm, 1998). Svanström (2016) described the experiences of health from participants with different health conditions after receiving intervention with Hjelm's FMT method. Interviews were analyzed using qualitative content analysis. The results distinguished between the two categories; increased well-being and strengthened resources. The category increased well-being was revealed in the subcategories better mood, reduced headache, better psychological health and better sleep quality. The category strengthened resources was revealed in the subcategories developed sensory, motor, cognitive, social, and emotional resources. The participants described experiences of increased perceived health (Svanström, 2016). Sjögren (2017) investigated, based on interviews, opinions of five teachers regarding using the intervention with the FMT method in a special school for pupils with learning disability. The overall result of the study suggested that the intervention has a positive effect and contributes to developing communication, body-function, social, cognitive, and emotional abilities (Sjögren, 2017). In a qualitative content analysis of diary notes in public documents, Svanström (2017) described experiences after individuals in need of care and rehabilitation participated in the intervention program with Hjelm's FMT method. The result consisted of the two main categories increased well-being and improved functioning, that was seen in the nine subcategories increased internal safety, improved mood, reduced pain, improved sleep quality, reduced fatigue, increased cognitive and perceptual abilities, increased mental and emotional resources and increased social abilities (Svanström, 2017). Through semi-structured interviews, Nollen (2025) investigated teachers' perspectives on Hjelm's HDF interventions and their potential to strengthen students' health and well-being. The result highlighted students' motivation and engagement, motor and cognitive development, participation and social interaction, and that the interventions may lead to cognitive skills and self-confidence among students (Nollen, 2025). Svanström (2021) described the experiences of relatives, caregivers, school staff and participants after individuals with congenital physical and intellectual disabilities participated in the intervention program with Hjelm's FMT method, by qualitatively analyzing diary notes in public documents. The two categories "greater well-being" and "better functioning" and the latent content "strengthen the individual's health and own resources" arised in the result (Svanström, 2021). While these previous studies indicate the potential utility of Hjelm's function-oriented intervention with Hjelm's FMT Method, when using more extensive formatting, a critical methodological and theoretical parameter remains unaddressed in the current literature: the specific role of timing and spacing. Existing research has predominantly evaluated applied timeframes following the guidelines of the Hjelm Approach –

which explicitly state that sessions should occur no more frequently than bi-weekly to prevent developmental stagnation – without defining the boundaries or lower thresholds of these effects. Consequently, to understand the mechanism of action and optimize future clinical resources, it is vital to examine how the passage of time itself modulates these neurodevelopmental outcomes.

BL3 One significant point in the natural functional development process is that it is connected to the factor of time. When children acquire developmental skills and milestones later than expected, it can lead to a diagnosis of developmental disabilities. Adolph & Robinson (2015) claim that the passage of time is a golden key parameter of development, however researchers have put aside addressing how time in fact contributes to developmental change and mostly have emphasized on time as period of developmental mechanism. So, it may be beneficial if research highlights the very number of events constituting an experience in the CNS and inside the body (Karen E. Adolph & Robinson, 2015). Similarly, Hjelm emphasizes that the number of actions, and events, within the child must be sufficiently high since it takes time to fulfil an experience in the CNS, and he also highlights that the number of those actions and events has not yet been presented in developmental theories, including Piaget' theories (Hjelm, 2005).

Researchers in cognitive development tend to define 'developmental time' primarily through chronological age, frequently overlooking other time scales that could be relevant to understanding growth and change (R. S. Siegler, 2006). *Nested time scales* refer to the idea that developmental processes occur across multiple, interconnected layers of time, ranging from short-term changes to broader, long-term developmental trends. It is important to consider these different time scales in order to fully understand human growth and development. Recent studies highlight the significance of addressing both immediate (e.g., daily interactions) and long-term (e.g., lifespan development) temporal factors, which often operate simultaneously (R. Siegler, DeLoache, & Eisenberg, 2011; Spencer, Blumberg, & Johnson, 2011).

For motor development researchers, the number of days between birth and the first appearance of a motor behavior is of certain interest, while only time passing has no specific explanation for the changes in the child (Saavedra, van Donkelaar, & Woollacott, 2012). Research on infants lacks fundamental information about developmental time, and it is important to consider what infants really do experience during natural development processes (Karen E. Adolph & Robinson, 2015). Each moment, infants spontaneously act and move (Karen E Adolph et al., 2012). Natural behavior and movement are presented by the infant without any special rules or directions, meaning that the actual experiences matter, not the empty passage of time (Karen E. Adolph & Robinson, 2015). Hjelm claims that sufficient length of time for the total period of his function-oriented intervention program, and also sufficient time between the program sessions, is needed in order to actually be able to influence the natural functional development of a person when using the intervention tool Hjelm's FMT method (Hjelm, 2005).

Many researchers have evaded the importance of the passage of time concerning its contribution to developmental changes, and existing research on Hjelm's HDF interventions has highlighted different aspects but not the time factor. In order to streamline and anchor future interventions with Hjelm's FMT method regarding the passage of time, in this study we investigated the importance of time in natural functional development by applying shorter time between sessions than Hjelm emphasizes on in the intervention. We have carried out our research by using Hjelm's FMT method as intervention program on motor and cognitive components in children with SLD while considering the time factor. In SLD, the delay in developmental skills in preschool age is usually not so severe that the family notices the disorder, but the consequences of this developmental disorder in higher years in education and other areas of life are significant. On the other hand, in SLD there is a problem in all aspects of development, and the use of an intervention that increases the overall developmental function and the ability of the CNS is important.

Therefore, the aim of this study was to investigate whether a structurally restricted timeframe—characterized by both a shortened total intervention period and reduced intervals between sessions—is sufficient to elicit developmental changes, thereby defining a minimum effective threshold for Hjelm's function-oriented intervention when using Hjelm's FMT method in children with SLD.

Materials and Methods

Study design

This is an experimental, a single-blind clinical trial. The assessors were blinded to the group allocation of participants. Also, the statistician who analyzed the data was blind to the grouping.

Participants

The sample were students with SLD in Tehran who were selected with convenience sampling. They were students referring to the five special rehabilitation and education centers for students with learning difficulties.

The inclusion criteria consisted of age 7 to 11 years, being diagnosed with SLD by psychiatrist and psychologist through the fourth version of the Wechsler Intelligence Test for Children and teacher-made educational tests, and parents' sufficient ability to read, write and speak in Persian (to complete the executive function questionnaire). The exclusion criteria consisted of physical, visual and hearing problems (that could not be compensated with assistive devices) and comorbid disorders (based on psychiatrist and psychologist reports) except for ADHD. The withdrawal criteria included non-cooperation of parents or child's unwillingness to refer to the intervention and assessment sessions, occurrence of problems, illnesses, or life events for the child that affected the results of the study.

Sample size

To determine the sample size, based on a similar study in terms of the outcomes and assessment tools in children with SLD (Kalantari et al., 2013), Considering $\alpha = 0.05$ and $\beta = 0.2$ and the formula to calculate the sample size for two independent groups in a clinical trial (figure 1), 6 subjects were calculated in each group. Due to the possibility of dropping in experimental studies, we tried to obtain about twice the sample. The disposition of the sample is demonstrated in figure 2.

[Figures 1 and 2 are about here]

Instruments

Behavior Rating Inventory of Executive Function (BRIEF)

It has two versions for parent and teacher, which were used in this study. It asks questions about the child's behavior in the natural context of life, behavioral assessment of executive functions in the home and school environment and is designed for the age range of 5 to 18 years. The BRIEF consists of 86 items with three-point Likerts, which are divided into 8 separate subscales including inhibit, shift, emotion control, working memory, initiate, plan, organization of material, and monitor. These eight subscales are divided into two general scales for scoring: "Behavior Adjustment Index" (BRI): includes the first three scales (inhibit, shift t and control emotions), and "Metacognition Index" (MCI): include remaining five scales (working memory, initiate, plan, organization of material, and monitor the. Examination of the internal consistency of the test showed Cronbach's alpha of 0.80 to 0.90 for both parents and teachers. The test-retest coefficient in BRI, MCI and Global Executive Composite (GEC) scales in parent form was 0.81, 0.83 and 0.80, respectively (Gioia).

Continuous Performance Test (CPT)

To measure sustained attention and distraction. This test is known as the most common laboratory tool in the diagnosis of sustained attention. The subject should draw attention to a relatively simple set of visual or auditory stimuli for a period of time and respond with the push of a button when the target stimulus appears. In most recent research, visual stimuli are presented for a short time on a computer screen. Must respond to the target stimulus by pressing one of the keyboard keys.

Persian form of test that is run through a computer. There are 150 Persian images as stimuli, of which 30 stimuli (20%) are considered as target stimuli and the remaining 80% are considered as non-target stimuli. The presentation time of each stimulus is 150 milliseconds and the time interval between the displays of the two stimuli is 500 milliseconds. According to the results of the study of Hadianfard et al. (2000), it has been determined that the Persian form of the continuous performance test has a valid and reliability. In their study, the reliability of retesting different parts of the test was between 59% to 93% (Hadianfard et al., 2000). In the present study, the response time and the number of correct detections are examined separately for the visual and numerical stimuli.

Wechsler Working Memory Scale (WMS)

The Wechsler Working Memory Test is one of the most common methods for assessing working memory by measuring the digit span (Wechsler, 1945). It consists of two parts: forward and backward digit width. In forward digits a series of numbers are presented, and the subject must repeat the numbers presented in the same order. The series of numbers is presented, and it is necessary for the subject to repeat the numbers in reverse order. In Iran, in a study that was conducted, the reliability coefficients by Cronbach's alpha for subscales ranged from 0.65 to 0.85. Reliability coefficients by halving method for subscales ranged from 0.62 to 0.84 and for indices ranged from 0.75 to 0.80 (Saed, Rushan, & Moradi, 2008). In the present study, the software version was used.

Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)

Evaluates motor skills in children aged 4.5 to 14.5 years. The complete set of this test consists of eight sub-tests (including 46 items). The test set provides a comprehensive indicator of motor proficiency. The complete test time is 60-45 minutes. This test is used to screen, evaluate progress, education planning or intervention and research. Three scales can be obtained: The Gross Motor Skills Scale, the Fine Motor Skills Scale, and the General Motor Skills Scale. The test has the necessary validity and reliability, so that the reliability of the retest set is 0.87 and its validity is 0.84 (Bruininks, 1978).

Clinical Observation of Motor and Postural Skills (COMPS)

This test is a screening tool for children aged 5-15 years to determine the presence of movement problems based on posture. In this study, its raw scores were used to measure the outcome of treatment. It is made up of six items derived from Aires integrated sensory assessments, which include slow movements, Rapid Forearm Rotation, Finger-Nose Touching, Prone Extension Posture, Supine Extension Posture, and Asymmetrical Tonic Neck Reflex (ATNR). This tool helps the examiner with standard instructions to diagnose coordination and movement problems based on postural problems. This test takes 15 minutes and is suitable for mild neurological problems such as learning disabilities, hyperactivity, motor coordination disorders and is not suitable for severe neurological disorders such as cerebral palsy, epilepsy and mental disorders. The retest reliability of this test is 0.92, the reliability between the testers is 0.87 and its internal consistency is also reported to be high (Wilson, Pollock, Kaplan, Law, & Faris, 1992).

Procedure

Initially, the research objectives and methodology were explained to the parents. Participants were selected using a convenience sampling method based on predefined inclusion criteria. Informed written consent was obtained from the parents through signed consent forms, and verbal assent was secured from the participating students. Following enrollment, participants were randomly assigned to either the intervention or control group using a simple randomization procedure with sealed envelopes, ensuring that group allocation remained concealed until the official start of the trial.

Parents completed the demographic information form. Assessments for this clinical trial, including the BRIEF, WMS, CPT, BOTMP, COMPS, were conducted both before and after the intervention by three occupational therapists trained by the project manager to administer the assessment tools. The control group did not receive any treatment between the two assessment points. In the experimental group, the intervention with Hjelm's FMT method was delivered by a function-oriented development specialist trained at Hjelm University, Sweden. Participants in this group did not receive any additional interventions. The intervention consisted of sixteen weekly sessions, each lasting 20 minutes.

During the intervention sessions, the function-oriented development specialist intervened with the intervention tool Hjelm's FMT method, based on the Hjelm Approach. The sessions were individual, and special adapted drums, cymbals and various specialized drumsticks, and sometimes adapted breath-sound-attribute, were provided to the child. The function-oriented development specialist played special melody signals on an acoustic piano. Each melody signal was connected to a specific arrangement and formation of drums and cymbals, with the purpose of developing the maturity of the child's movement pattern. Also, by placing the drums in different heights and positions relative to the child's body, the child could spontaneously experience new movement patterns resulting in elevated overall functions of the body and the CNS. Using different specialized drumsticks during the session, the child was attracted to spontaneously change the position of the sticks in the hand which successively developed the maturity of the hand function. The intervention was completely nonverbal, not using any verbal instructions or language conversation, according to the Hjelm Approach. When the child unconsciously discovered a certain movement pattern through spontaneous trials, the function-oriented development specialist played a specific melody signal on the acoustic piano connected to that movement pattern.

Data analysis

Differences in demographic characteristics between the two groups were investigated at baseline using Chi-squared test and t-test. Normality and equality of variances for all data were checked. The effect of the intervention on motor and cognitive variables was evaluated by Repeated-measures ANOVA. The main effects of time and group were calculated, so that time as within-subjects variable and group as between-subjects variable were considered. Also, time × group interactions were examined for all outcomes. For the outcomes that a significant change in time-group interaction were found, the paired t-test was calculated to compare pre- and post-values for the groups separately. Significance level was set at $p < 0.05$. Data were analyzed using SPSS® Version 18 (SPSS Inc., Chicago, IL, USA).

Results

In the present study, 19 children (9 = intervention group; 10 = control group) participated. These subjects were in the age range of 7-12 years with a mean 8.5 (SD = 1.3). The independent sample t-test and Chi-square test showed that the two groups had no significant differences in age and other demographic characteristics that are presented in table 1 ($P > 0.05$). In both groups about fifty percent of the students were in the second grade. The sample received almost no rehabilitation and medical treatment during the study (except for one subject in the intervention group and two subjects in the control group). In the intervention group, the number of boys was twice that of girls, but in the control group, the ratio was exactly 1:1 (table 1).

[Table 1 about here]

Using repeated-measure ANOVA, no significant difference was found in cognitive outcome measures including the BRIEF, CPT, and WMS ($P > 0.05$). These results are presented in table 2.

[Table 2 about here]

According to table 3, there was no significant Time × Group interaction (F [1, 17]; $P > 0.05$]. But there were significant effects of time as the within-subjects variable that means a significant change had been happened within the groups. The scales of BOTMP including the gross motor skills, coordination and total scales, as well as postural motor skills in the COMPS, had been significantly changed ($P < 0.05$). To more accurately detect changes within groups, the paired t-test was done.

[Table 3 about here]

The results of paired t-test on the variables that repeated-measure ANOVA demonstrated within group effect of the intervention with Hjelm's FMT method are presented in table 4. The gross, coordination, and total motor scores were significantly changed in the intervention group ($P <$

0.05). There were some positive changes in the control group, too. The postural, coordination, and total motor skills were significantly improved in the control group ($P < 0.05$).

[Table 4 about here]

Discussion

The findings of the present study indicated the following summary results for the two groups of children with SLD: the intervention group demonstrated improvement in gross motor skills, as assessed by BOTMP; both groups showed improvements in motor coordination and the total motor proficiency score based on the BOTMP; the control group exhibited improvement in postural motor skills, as measured by the COMPS. Each group, when analyzed separately, showed progress in motor coordination and total motor skills but did not demonstrate any significant changes in cognitive skills. The key distinction between the groups was that the intervention group experienced significant improvements in gross motor skills, whereas the control group showed significant improvements in postural motor skills. Within-group analyses also revealed some non-significant changes, including regressions in certain variables in the intervention group. Overall, the intervention did not yield statistically significant differences between the two groups. Each of these findings has been discussed in following.

Improvements in the intervention group

Although the between-group differences did not reach statistical significance, the minor positive trends observed in certain parameters within the intervention group should not be entirely dismissed. Rather, these subtle changes may be interpreted as an indication of an initial developmental process being initiated. Such an overall initial process involves a chain of molecular, cellular, structural, and physiological events, where certain developmental steps occur before others and depend on them (Kleim & Jones, 2008). The findings about improvement in the intervention group are in some way similar to research that applied some forms of motor intervention in SLD (Esmaili et al., 2017; Fathi Azar, Mirzaie, Jamshidian, Hojati, & Development, 2023; Rameckers, Crafford, Ferguson, & Smits Engelsman, 2023). Too, our findings of small improvement may be justified by perspectives on perception, action, body and cognition. The perspective of the "perception-action-coupling" (Getchell, Mackenzie, & Marmon, 2010) is demonstrated when participants were stimulated by melody signals. For producing adaptive and integrated movements, perceptual inputs should collaborate with some units of actions (Getchell et al., 2010). Due to neural connections between auditory and motor areas, audio-motor interactions proceed (Danna et al., 2015). In our study, the melody signals used in Hjelm's FMT method act as a perceptual stimulus to create the right conditions and motivate the person to work with his own body in spontaneous movements that will be organized continuously (Hjelm, 2005). The functional relationship between perception and action can also be explained by "Theory of Event Coding", expressing multistory, visual and kinematic signals will be integrated with the auditory feedback resulting in an integrated perception of that event, which can be reactivated when new information has to be processed (Danna et al., 2015). However, due to the intentional temporal constraints of this applied timeframe, the restricted timeframe was evidently insufficient to allow these early neurodevelopmental processes to consolidate into robust, statistically measurable clinical effects. This supports the hypothesis of a minimum effective threshold for the intervention.

Non-significant changes in some variables and regressions in certain variables in the intervention group

Our study shows no changes in cognitive skills and even regression in some variables of motor skills in the intervention group. This is in line with Hjelm's view that neglecting the time factor in natural functional development may lead to stagnation or even regression (Hjelm, 2022a). These findings are contrary to studies which used other interventions for this target group, for example Rameckers et .al (2023) applied a neuromotor task training on motor performance (Rameckers et al., 2023). Azizi et.al (2018) applied a specific individualized cognitive rehabilitation training for sustain attention (Azizi, Drikvand, & Sepahvandi, 2018). Esmaili et.al (2017) used play-based therapy on the metacognitive and behavioral aspects of executive function (Esmaili et al., 2017). These mentioned studies described progress in motor or cognitive aspects in the intervention group. As previously mentioned, an insufficient timeframe for allowing early neurodevelopmental processes to consolidate can be considered as a reason to our result in the intervention group. In addition to that reason, the result of no changes in the cognitive skills and regression in some variables of motor skills could also be explained by the fact that the early stages of an intervention concerning deep brain stimulation and synaptic responses often tend to degradation, and synapse enhancement appears in later stages of the intervention process. Therefore, the intervention must have sufficient length in time to stabilize the changes (Kleim & Jones, 2008), which is also demonstrated by Hjelm claiming that a short time interval between the sessions in his HDF interventions, especially regarding target groups in the elementary school, such as students' with SLD, may block the natural spontaneous functional development and may even regress it (Hjelm, 2005). Adolph & Robinson (2015) emphasized the importance of time in development (Adolph & Robinson, 2015). In line with this, de Beukelaar (2015) provided neurological support for the time factor, showing that shortly after the acquisition and consolidation of memory connected to motor activity, interventions provided at a specific time can either increase or even destroy the consolidation, meaning that consolidated memories can re-enter a temporary unstable state when reactivating during retrieval. So, they need to be re-established to last longer (de Beukelaar, 2015). Hjelm (2022) points out: *"We must always expect a visible loss of the acquired experience, a temporary drop in the levels of performance"* (Hjelm, 2022b, p 3). Such reconsolidation depends on a particular time when it exists, and previously established memories are vulnerable to distraction and are temporarily prone to be "destroyed". Reconstruction does not rely on additional motor interventions, but instead it occurs over time (de Beukelaar, 2015). This is also in line with Hjelm (2022) saying: *"In all development, time is important… when it comes to the development curve of human functional development, it is impossible to try to manipulate time. There is no form of express development"* (Hjelm, 2022b, p 4). So, it seems that especially the interval between the intervention sessions, and also the length of the total intervention period, in the present study was too short, when dealing with spontaneous natural functional development, according to mentioned research and to the statement of Hjelm (2022): *"The intervention can produce desired effects with about 10-15 sessions per school term (per half a year), about 20-30 sessions per 52 weeks long year… for example every other week for individuals in elementary school… since the concepts of training and exercise do not exist within the FMT method, all is based on natural functional development. The FMT method is based on… each phase of the development curve must be anchored before the next phase can be built"* (Hjelm, 2022a, p 2). Consequencely, long-term interventions, but especially sufficient long time or time breaks between intervention sessions, are needed to establish and increase changes and promote the natural functional development process (Hjelm, 2005).

Improvements in the control group

The progress of the control group can be explained in terms of plasticity of the brain. Development is synchronized with neuroplasticity from the neuroscience perspective. A healthy brain as well as a damaged brain have the same principles regarding that the brain is permanently rebuilding its neural circuitry to encode new experiences and changes in behavior. Such a process is the key to regenerating the remaining tissues of the damaged brain, and even without rehabilitation, the damaged brain can adaptively learn (Kleim & Jones, 2008). This "neurological spontaneous recovery" is an effective and complex biological process (Kwakkel, Kollen, & Lindeman, 2004). In the present study, the neurological spontaneous recovery seems to be a reason for development in the control group. Zentner (2010) claims that the brain areas involved in auditory-motor coordination may operate from an early age in almost automatic ways, and human being displays spontaneously rhythmic body movement to rhythmical patterns from infancy (35). Synchronization requires a degree of motor control which may occurs in preschool age (Zentner & Eerola, 2010). Even so, Kwakkel et al (2004) show that there is not enough reliable measurement method to evaluate the effective recovery time, and that the function of time itself is a predictor of spontaneous recovery and can be studied independently (Kwakkel et al., 2004). Therefore, it is suggested that follow-up studies are needed to distinguish between, on the one hand, the neurological spontaneous recovery or development of the brain in general, and, on the other hand, natural spontaneous functional development through the intervention tool Hjelm's FMT method when leading to significantly more matured human functional level.

A notable finding in our data is that the control group demonstrated robust within-group improvements, particularly in total motor scores ($dz = -1.49$, 95% CI [-2.33, -0.63]), which descriptively exceeded the changes observed in the intervention group. Rather than indicating a lack of inherent efficacy of Hjelm's function-oriented intervention method, this pattern strongly reinforces our theoretical boundary hypothesis. In children with SLD, spontaneous maturation and test-retest learning effects routinely contribute to incremental changes over a 16-week period, as seen in the control group. However, by imposing an insufficient temporal framework (in particular an inadequate spacing between sessions), the intervention group's natural functional developmental trajectory may have been fragmented or subjected to stagnation, preventing the consolidation of neurological changes. This lack of an additive effect in the intervention group compared to the control group empirically demonstrates that the applied timeframe falls entirely below the minimum effective threshold required to engage the CNS productively.

Conclusion

For conclusion, since many researchers have neglected the main issue of how time affects change and developments in human beings, the present study aimed to investigate whether a structurally restricted timeframe—characterized by both a shortened total intervention period and reduced intervals between sessions—is sufficient to elicit developmental changes, thereby defining a minimum effective threshold for Hjelm's function-oriented intervention when using Hjelm's FMT method in children with SLD. Our findings may benefit future studies and streamline future interventions with Hjelm's FMT method regarding the importance of the time factor in the Hjelm Approach when promoting the natural functional development. Consequently, the Hjelm

Approach could be anchored in future studies on Hjelm's FMT method for people with SLD and for other target groups by not having too short total length of the intervention period and especially not having the intervention sessions on every week basis but instead having sufficient length of time intervals between intervention sessions. By defining the minimum time threshold for natural functional development of motor and cognitive skills through this study, future research on the Hjelm approach and on Hjelm's HDF interventions may be optimized and future research resources can be used wisely.

Ethical Considerations

Compliance with ethical guidelines

The trial was done based on the Declaration of Helsinki and approved in the Ethics Committee of Iran University of Medical Sciences (Code: IR.IUMS.REC.1398.974). This trial was registered prospectively in the Iranian Registry of Clinical Trials (IRCT) (No. IRCT20100224003419N5).

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Authors' contributions

Conceptualization and methodology, all authors; Validation, Samaneh Karamali Esmaili and Mitra Khalafbeigi; Formal Analysis, Samaneh Karamali Esmaili and Mitra Khalafbeigi; Investigations, Mitra Khalafbeigi and Samaneh Karamali Esmaili; Resources, Mehdi Alizadeh Zarei, Mitra Khalafbeigi and Samaneh Karamali Esmaili; Data Curation, Samaneh Karamali Esmaili; Writing (original draft, review & editing), all authors; Visualization, Samaneh Karamali Esmaili and Mitra

Khalafbeigi; Supervision, all authors; Project Administration, Mitra Khalafbeigi; Funding Acquisition, Samaneh Karamali Esmaili.

Conflict of interest

The authors declared no conflict of interest.

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Tables/Figure Legends

Figure. 1 The formula of calculating the sample size

Figure. 2 The participants' flowchart

Table 1 Demographic characteristics of the participants

Table 2 Repeated-measures ANOVA for cognitive outcome measures

Table 3 Repeated-measures ANOVA for motor outcome measures

Figure. 1 The formula of calculating the sample size

$$n_1 = n_2 = \frac{({S_1}^2 + {S_2}^2)(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta})^2}{(\bar{X}_1 - \bar{X}_2)^2}$$

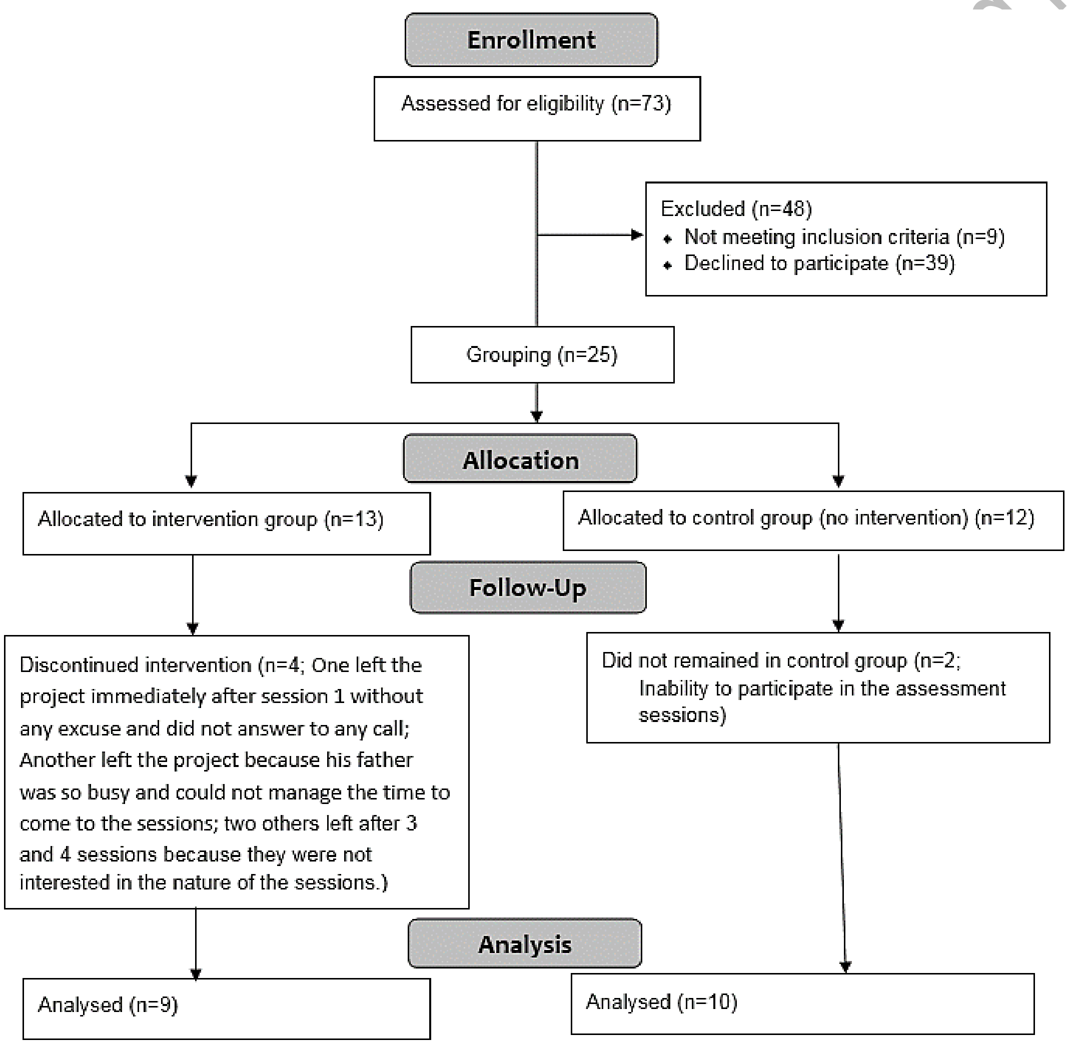

Figure. 2 The participants' flowchart

Table 1- Demographic characteristics of the participants

	Intervention group (n = 9)	Control group (n = 10)	P-value
Gender			
Male	6 (66.6)	5 (50)	0.46
Female	3 (33.3)	5 (50)	
Grade			
First	1 (11.1)	2 (20)	
Second	4 (44.4)	5 (50)	
Third	2 (22.2)	1 (10)	0.74
Fourth	1 (11.1)	1 (10)	
Fifth	0	1 (10)	
Sixth	1 (11.1)	0	
Siblings			
No	1 (11.1)	2 (20)	
One	5 (55.5)	3 (30)	0.21
Two	3 (33.3)	2 (20)	
Three	0	3 (30)	
Comorbidity of ADHD			
No	8 (88.8)	8 (80)	0.59
Yes	1 (11.1)	2 (20)	
Therapy services			
No	9 (99.9)	9 (90)	0.62
Speech therapy	0	1 (10)	
Medication	1 (11.1)	1 (10)	

Data are presented as number (percent); ADHD = Attention deficit/hyperactivity disorder

Table 2 - Repeated-measures ANOVA for cognitive outcome measures

Variable		Group			Time			Interaction time × group		
		F [1,17]	**Partial η²**	**P-value**	**F [1,17]**	**Partial η²**	**P-value**	**F [1,17]**	**Partial η²**	**P-value**
BRIEF	Composite Index	0.067	0.004	0.798	0.997	0.059	0.333	0.234	0.014	0.635
	Behavior Regulation Index	0.004	0.000	0.951	7.008e-4	0.000	0.979	0.309	0.019	0.586
	Meta-Cognitive Index	0.130	0.008	0.723	3.010	0.158	0.102	0.086	0.005	0.773
CPT	Response time to numbers stimulus	1.630	0.087	0.219	1.964	0.104	0.179	0.012	0.001	0.914
	Response time to pictures stimulus	1.563	0.084	0.228	1.164	0.064	0.296	0.580	0.033	0.457
	Correct detection to number stimulus	2.383	0.005	0.141	0.094	0.005	0.763	1.044	0.058	0.321
	Correct detection to picture stimulus	2.491	0.128	0.133	0.115	0.007	0.738	0.590	0.033	0.453
WMS	Auditory memory	1.206	0.066	0.287	1.481	0.080	0.240	0.540	0.031	0.472
	Visual memory	0.929	0.052	0.349	0.968	0.054	0.339	1.521	0.078	0.234
	Backward memory	0.571	0.032	0.460	0.493	0.028	0.492	1.699	0.091	0.210
	Foreward memory	1.143	0.063	0.300	0.895	0.050	0.357	0.895	0.050	0.357
	Memory span	1.262	0.069	0.277	0.071	0.004	0.793	0.872	0.049	0.363

BRIEF = Behavior Rating Inventory of Executive Function; CPT = Continuous Performance Test; WMS = Working Memory Scale

Table 3 - Repeated-measures ANOVA for motor outcome measures

Variable		**Group**			**Time**			**Interaction time × group**		
		F [1,17]	**Partial η²**	**P-value**	**F [1, 17]**	**Partial η²**	**P-value**	**F [1,17]**	**Partial η²**	**P-value**
COMPS	Postural-motor skills	2.035	0.107	0.172	5.187	0.234	**0.036***	4.104	0.194	0.059
BOTMP	Gross motor skills	0.343	0.20	0.566	11.02	0.393	**0.004***	0.511	0.029	0.484
	Fine motor skills	1.222	0.067	0.284	3.947	0.188	0.063	2.256	0.117	0.151
	Coordination	0.045	0.834	0.003	20.970	0.552	**0.000***	0.839	0.047	0.373
	Total score	0.083	0.005	0.777	25.895	0.604	**0.000***	1.064	0.059	0.317

COMPS = Clinical Observation of Motor and Postural Skills; BOTMP = Bruininks-Oseretsky Test of Motor Proficiency; *$P < 0.05$

Table 4- Paired t-test comparison between pre- and post-test on the postural, gross, coordination, and total motor scores

		Intervention group (n = 9)			**Control group (n = 10)**		
		t	P-value	*95% CI (d_z)*	t	P-value	*95% CI (d_z)*
COMPS	Postural-motor skills	-0.152	0.883	*[-0.71, 0.61]*	-3.64	**0.005***	*[-1.92, -0.37]*
BOTMP	Gross motor skills	-2.78	**0.021***	*[-1.70, -0.15]*	-1.83	0.099	*[-1.24, 0.10]*
	Coordination	-3.46	**0.009***	*[-1.97, -0.32]*	-3.35	**0.008***	*[-1.81, -0.30]*
	Total score	-2.64	**0.03***	*[-1.64, -0.11]*	-4.7	**0.001***	*[-2.33, -0.63]*

COMPS = Clinical Observation of Motor and Postural Skills; BOTMP = Bruininks-Oseretsky Test of Motor Proficiency; *$P < 0.05$