The effect of Spatial Training in Dance Education on Spatial memory in Children with Duchenne muscular dystrophy

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Abstract. Duchenne muscular dystrophy (DMD)is a genetic disorder that affects motor function and is often accompanied by cognitive deficits, particularly in spatial perception and working memory. Motor interventions have been proposed as a potential method to improve cognitive function in children with DMD. The aim of this study was to investigate the effects of spatial perception training on spatial memory in children with DMD through dance education. The spatial working memory task was used to assess the spatial memory ability of two groups of children through an experimental design. The results indicated that the children who received dance training were better than the untrained children in terms of accuracy and reaction time, suggesting that dance training can effectively enhance spatial working memory, executive function and spatial perception in children with DMD. The study provides empirical research evidence for the use of dance as a cognitive intervention in DMD rehabilitation, and provides a theoretical basis for future intervention strategies and clinical treatment protocols. However, due to the limited sample size, the extensiveness and applicability of the results of this study still need to be further verified.

Keywords: Duchenne muscular dystrophy, Spatial memory, Motor interventions, spatial perception training

1. Introduction

Rehabilitation of children with rare diseases has become an issue of concern for medical researchers in recent years. Duchenne muscular dystrophy (DMD) is an X-linked hereditary disease mainly caused by mutations in the gene for myotonic dystrophy proteins, and the incidence rate of neonatal male infants is 1/3,500 to 1/6,000, and the main clinical manifestations are decreased sexual muscle strength, motor function and even cognitive, behavioral and socio-emotional problems. The main clinical manifestations of children with DMD are decreased sexual muscle strength and motor function, and even cognitive, language, behavioral and socio-emotional problems. The onset of the disease starts at 3 to 6 years of age, with progressive weakness of the limbs, and the child usually loses the ability to walk around 10 years of age, and often dies before 30 years of age due to respiratory and cardiac failure [1]. A study showed that among 59 boys with DMD, 44% had learning disabilities and 32% had attention-deficit/hyperactivity disorder. Yet at the same time, this period is the best shaping period for children to learn ways of social adaptation and to build up new patterns of thinking and behaviors, so DMD has a serious negative impact on children's social adaptation and development of thinking [2]. Due to the differences in performance between individuals, researchers have not been able to conclude a generalized intensity of perceptual and motor training for groups of children, and most of the rehabilitation studies on children have been limited to the physical level, while few studies have been carried out to improve the cognitive and memory levels of children.

Exercise interventions can be used to directly improve cognitive and behavioral functioning in children. Regular participation in physical activity, such as short bouts of moderate-intensity exercise, has been shown to have significant cognitive benefits in school-aged children [3]. In recent years, experience of clinical treatments for patients with DMD has significantly slowed the rate of progression of their disease, with movement therapy playing a key role. Dance, as a creative movement that emphasizes proprioception and explores multisensory stimuli through the medium of the body, integrates and relies on a wide range of cognitive functions, including memory, attention, executive function, psychomotor speed memory, and social cognition and emotion. Also, it can

motivate children to explore three-dimensional space, experience variations in height, depth and breadth, as well as to feel spatial sharing and enhance their ability to interact with the environment [4-5]. Memorizing sequences of steps during dance, coordinating hands and feet, maintaining consistency of movement with the rhythm of music, and understanding the direction and location of the space around them can all improve children's spatial executive functioning [6]. Meanwhile dance-based cognitive stimulation therapies can help maintain or even improve cognitive abilities, especially attention and spatial perception [7]. As spatial ability has a significant impact on learning and life, improving children's spatial cognition and memory plays a crucial role in promoting child development [8].

It has been shown that children with DMD often have difficulty understanding the non-literal language of others and non-verbal communication cues, and most of them have cognitive impairments, with the working memory index being the most severely impaired, whereas the development of motor control can increase learning opportunities through interaction with the social environment [9].

However, due to factors such as low prevalence, individual differences in condition, and the vulnerability of the child, no objective interventions have been developed for the intensity of rehabilitation training, even though for many years some exercise training has been considered harmful, which may increase muscle damage and injuries, and there are no definitive guidelines for exercise training for people with DMD [10]. Research based on the cognitive dimension is equally scarce. On this basis, this paper will incorporate dance movement sequence memory and relatively gentle training methods to activate patients' deep muscles and enhance body perception, and assess children with DMD using a spatial working memory task, to delve deeper into whether spatial perception training in dance education can help to enhance their memory, executive abilities, and thus further contribute to the children's ability to social adaptation and executive ability, and alleviate the symptoms of the disease [11]

2. Research methods

2.1. Subjects and research procedures

In this study, eligible children with DMD (n=20) were selected from the University of Hong Kong Shenzhen Hospital as subjects through the experimental method, and were divided into two groups, the experimental group and the control group, according to whether they had received dance training or not, and were tested on the same spatial task respectively. All participants were children diagnosed with Duchenne muscular dystrophy (DMD), aged 3-8 years old, which is a critical period for the development of spatial awareness in children; only male children were included in the study due to the fact that boys are the majority of DMD children and there is a gender difference in the manifestation of the disease; all participants were required to have the ability to walk independently, and were assessed by a doctor for their suitability for dance training (assessment included rehabilitation and cardiorespiratory fitness, or spinal and hip X-rays within the last 3 months). In order to control for the effect of study duration on the results of the study, all participants in the experimental group were required to complete the same number of dance training sessions, a total of 24 sessions, each of which was 1 hour in length, with the aim of avoiding excessive strain on the children's physical strength and concentration from prolonged training, and thus maintaining the appropriate intensity of the experimental intervention. The children were trained weekly according to the study design (See Table 1), and to deepen dance content in a sequential manner according to the objectives of the design program from simple to complex, and the children's cognition was gradually stimulated according to the sequence of body perception, spatial perception, and spatial memory. Each class ensures the attendance of every participant, and the classroom environment includes a simple and uncomplicated visual design, a quiet and non-disturbing acoustic environment, and an open main training area in order to provide the children with a richer perceptual space, as well as an

auxiliary area for parental accompaniment and rest, so as to facilitate timely handling of emergencies for the children.

Table 1. Dance training designed to enhance spatial perception for children with DMD.

Content	Training purpose
Hand Clapping	To issue instructions to clap different parts of the body to increase children's self-body perception and synergistic movement (Liu, 2024).
go & stop rhythmic response	Enhance children's perceptual sensitivity through music.
Enlightenment training of direction perception	During the process, children are guided to point to different directions in space and dance in different spaces (e.g., low, middle, high, front, back, left, right).
<Good Time>	The movement sequence memory of the finished dance is linked to the spatial working memory.

Two groups of children were asked to complete the Spatial working memory task to test their spatial memory abilities, and the assessment was conducted in the lounge of the University of Hong Kong Shenzhen Hospital [11]. All participants sequentially entered the same experimental room to perform the manipulation and were tested individually, with no interference from anyone other than the instructor of the manipulation as well as the subject, and controlled for no other noises, and no obvious brightly colored elements that could divert the child's attention. For the test of spatial memory training, the children's memory will be stimulated in time after the completion of each session, e.g., by allowing the children to complete the dance combinations on their own, thus checking the degree of digestion of the content in a timely manner. The core curriculum includes the following three parts: (1) Go & Stop: the teacher plays rhythmic music and instructs the children to dance freely when instructed to ‘Go’ and remain still when instructed to ‘Stop’, in order to train the children's sense of rhythm, The purpose is to train the children's sense of rhythm and the ability to start and stop movements; (2) hand clapping and spatial perception training: instruct the children to point their body parts in different directions according to the instructions and change their movements according to the rhythm of the music between high, medium and low spatial heights to cultivate a sense of direction and spatial orientation; (3) finished dance ‘Good Time’: design a set of simple dance sequences based on the acceptance level of the children and demonstrate and explain them step by step. A step-by-step demonstration and explanation was given, and the process was repeated with the aim of improving spatial memory and execution ability by remembering the movement sequences.

2.2. Research tools

The experiment referred to the spatial WM task in non-verbal working memory employed in the study on localised areas of frontal and parietal cortex published by Fedorenko et al. in 2013, and E-prime was used for programming to design the spatial working memory task. Given the limited comprehension of preschoolers, the original material (See Figure 1) was replaced with a solid space for a smiley face, the inclusion of two elements at a time was reduced to one, and the 3x4 squares were replaced with 3x3 squares to accommodate the cognitive abilities of children with DMD [11]. Since only humans, regardless of age, spontaneously extract spatial relationships between successive items and use internal language to compress sequences in working memory, this experiment migrated the task for adults to be implemented for children (See Figure 2) [12]. At the beginning of the experiment, the attention point ‘+’ appeared, then four pictures appeared sequentially in each question, and the interval between two pictures was 1000 ms. Subjects were required to keep track of the positions of four different smiley faces while associating the overlapped morphology of the four pictures during the process, and were provided with two choices after the presentation of the pictures, and the maximum reaction time of the two options was 3750 ms. The maximum reaction time limit was 3750ms, where the wrong option was different in one or two places relative to the correct option. The child needs to store the set/sequence of elements in memory in a short period of time. It

hypothesises that children with dance training would outperform children without dance training in terms of accuracy and reaction time in the task.

SPSS 21.0 was used to process and statistically analyse the data.

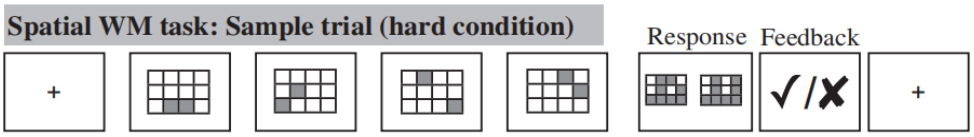

Fig. 1 Functional Specificity for High-Level Linguistic Processing in the Human Brain, by Fedorenko Et Al, 2011, Copyright by PNAS (Photo/Picture credit: Original).

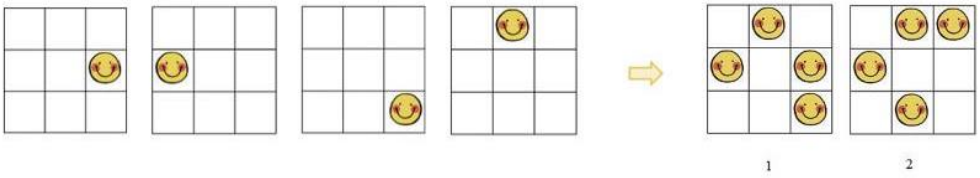

Fig. 2 The Program after the Adaption (Photo/Picture credit: Original).

3. Results

Independent samples t-tests were conducted on the correct rate and reaction time of the experimental and control groups. The results of the test showed that there was a significant difference in accuracy rate in terms of whether or not they had received dance training, with those who had received dance training (M=.43, SD=.31) having a higher accuracy rate compared to those who had not received dance training (M=0.78, SD=0.28), t(18)=2.66, p=.016; and there was a significant difference in reaction time in terms of whether or not they had received dance training, with those who had not received dance training (M=2573.04, SD=808.26) having a better accuracy rate compared to those who had not received dance training (M=.43, SD=0.28). Trained (M=2573.04, SD=808.26) had faster reaction time, t(18)= -2.15, p=.045, compared to those who were trained (M=1822.26, SD=750.44).This result suggests that dance training may enhance spatial memory ability in children with DMD.

4. Discussion

This study confirms that appropriate spatial dance training enhances the cognitive abilities of children with DMD, specifically in the area of spatial memory. Comparing the cognitive problems of DMD patients with ADHD may have a negative impact on their quality of life due to their poor facial recognition [13]. Therefore for children with DMD who have motor function, dance may be used to improve their cognitive and executive abilities. However, some aspects of cognitive functioning may be impaired even in boys without intellectual disability and executive functioning plays an even more important role in specific aspects of cognitive impairment in Duchenne muscular dystrophy, so targeting the programme with a goal-oriented approach to improve cognitive functioning and mitigate possible executive functioning deficits could target the group of children with DMD to reduce the cognitive Risk of Impairment [14]. The integration of cognitive rehabilitation activities into the rehabilitation of children with special needs is also an important building block in educational rehabilitation today [12].

While studies have demonstrated a training approach from a sensory perspective, such as through the qualitative results of dance therapy interventions for physically ill and weak children, which alleviated and soothed the children's ailments, and provided positive emotional support for the children and their family members, and while DMD children's perception of quality of life is mainly expressed in the leisure activity domain, so appropriate exercise helps to improve their quality of life and maintain children's natural development [15-17].

In addition, due to the limitations of the experiment, the number of subjects was small, thus making it difficult to generalize the results of this experiment, and it was also not possible to test the relationship between genotype and phenotype of the affected children. When the relationship between genotype and phenotype is examined, it will help to better understand the molecular mechanisms underlying the development of DMD, better predict the natural course of the disease, so that targeted measures can be taken to slow down the progression of the disease, and to analyze which specific rehabilitation tools (e.g., exercise training, physiotherapy, or choreography) are better able to respond to a particular mutation pattern, so that intervention strategies can be optimized. Furthermore, the spatial memory experiments in the setup part of this experimental study focused only on two-dimensional space, which differs from realistic three-dimensional spatial scenarios. Even though the two-dimensional task helps to standardize the assessment of spatial memory ability of children in specific dimensions, it does not fully represent their performance in complex three-dimensional environments. In real-life situations, for example, spatial memory ability usually requires the integration of depth information with multidimensional cues in dynamic environments. Despite these limitations, research has shown, through the underlying mechanisms of spatial memory, that people with DMD can improve their spatial memory abilities through dance training.

The physical functioning of people with DMD has improved significantly over the past decades, but improving their quality of life (QOL) remains an important issue. In the future, with the in-depth research on the mechanisms of cognitive dysfunction in DMD, it is expected that cognitive enhancement will be incorporated as a core component of rehabilitation therapy through a more multidisciplinary approach, helping children to better adapt to complex social environments, and to enhance their learning ability, autonomy, and social interaction skills. At the same time, this kind of comprehensive intervention not only helps to improve the children's daily life experience, but also reduces the psychological and economic burdens for the families and the society, and realizes the common progress of medical treatment and education.

5. Conclusion

This study investigated the effects of spatial training in dance education on spatial memory in children with Duchenne muscular dystrophy. Findings indicated that dance training greatly improved accuracy and reaction time on spatial memory tasks, highlighting its potential to enhance cognitive abilities such as spatial perception and executive function. This suggests that incorporating dance-based interventions into DMD rehabilitation programs can effectively support cognitive and motor development while fostering social adjustment. These findings also underscore the importance of structured interventions tailored to the unique needs of children with DMD.

In summary, this study provides a theoretical foundation for integrating dance into rehabilitation strategies and offers innovative insights into improving the quality of life for children with DMD. More further research should involve larger sample sizes and more complex spatial tasks to validate and extend these findings.

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