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ITI MÜÜRSEPP

Sensorimotor and social functioning in children with developmental speech and language disorders

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LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following original papers, which will be referred to in the text by Roman numerals (I–III):

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The dissertant had primary responsibility for protocol development, subject screening, performing measurements, preliminary and final data analysis, and writing of the manuscripts.

ABBREVIATIONS

AD	–	articulation disorder
BL	–	bilateral
BM	–	body mass
BMI	–	body mass index
CG		control group
CMJ_{height}	–	counter-movement jump height
CMJ_{force}	–	peak vertical ground reaction force during counter-movement jump
DSLD	–	developmental speech and language disorder
EPs	–	exploratory procedures
HOR	–	haptic object-recognition
HRT	–	half-relaxation time
IEL	–	impairment of expressive language
IS	–	impairment score
LAT_C	–	latency of contraction
LAT_R	–	latency of relaxation
LE	–	leg extensor
M-ABC	–	Movement Assessment Battery for Children
MMDT	–	Minnesota Manual Dexterity Test
MVC	–	maximal voluntary contraction
RFD_{50}	–	rate of force development at the level of 50% of MVC
SI	–	social interaction
SLI	–	specific language impairment
SSD	–	speech sound disorder
UL	–	unilateral
UL_{grip}	–	unilateral maximal isometric hand-grip strength
UL_{left}	–	unilateral contraction of the left leg
UL_{right}	–	unilateral contraction of the right leg

1. INTRODUCTION

Speech and language play a critical role in children's learning environment (Reeves 1995). Most children acquire language with surprisingly little effort and by the age of five, the grammar of the mother tongue is basically mastered (Fromkin and Rodman 1998). However, a substantial number of children fail to develop speech and language skills as expected. Developmental speech and language disorder (DSLD) is the most common chief complaint for preschool-age children (Webster et al. 2006, Newmeyer et al. 2007).

Currently, DSLD is diagnosed in children with significant language problems with unknown cause and with no other obvious impairments (Tomblin et al. 1997, Leonard 1998). Paradoxically, studies have shown that despite an initial diagnosis of isolated speech and language disorder, it may be associated with problems in cognitive functioning (Webster et al. 2004), with academic difficulties (Young et al. 2002, Flax et al. 2003) and behavioural (Lindsay and Dockrell 2000, Redmond and Rice 2002, Alcock 2006) or psychiatric disorders (Miniscalco et al. 2006). Language abilities and academic achievement in school-aged children with significant DSLD has been intensively studied during the two last decades and aberrancies in these areas are confirmed.

Several studies have also enlightened the area of motor functioning of children with speech and/or language disorders. DSLD has long been associated with detriment of fine-motor skills, because speech production requires well-coordinated movements of articulators. There is solid evidence that impaired fine-motor skill is common co-morbidity of severe speech disorders like aphasia that involves dysfunction of brain structures. Studies that have recruited children with severe DSLD without known cause (e.g. impairment of the brain) have also confirmed occurrence of problems in fine-motor performance or eyehand coordination. More controversial are results in children with unspecified severity of DSLD, where fine-motor skills involvement in dysfunction is not definite.

Unfortunately, gross-motor skills have attracted less interest of investigators and only recent studies have handled this subject. Few of these studies have assessed functional motor performance (gait, balance, hopping) in preschool-aged children, but preferred subjects have been school-aged children with persistent DSLD, and the link between severe DSLD and gross-motor function has been found. In children with DSLD, there are missing data about maximal voluntary contraction (MVC) force and rapid force-generation and relaxation capacity that are important indicators of neuromuscular performance and movement control.

Haptic perception or stereognosis is the ability to recognize objects without vision, only by touch. It is a complex ability requiring sensory, motor and cognitive competence. There is limited information regarding haptic object-recognition in children with DSLD, but the few investigators who have evaluated speech disordered children, have shown disturbed ability to recognize objects by touch. Assessment techniques that have been used in these studies are complicated and it is difficult to define the exact level of impairment.

Scientists agree that children with DSLD are at risk for behavioural and social difficulties (Redmond and Rice 1998, Conti-Ramsden and Botting 2004). It is evident that significant DSLD affects one's social relations because of the unintelligible speech, but questionable is how exactly social isolation or lower acceptance by peers influences child's development in other domains. It has been hypothesized that adults with speech disorders experience lower social participation and quality of life.

The problem is that majority of children with DSLD have mild to moderate impairment not requiring intensive treatment programs, but conducted studies have mostly concentrated on the minority of these children who have severe impairment and attend to special schools or are recruited through clinics. We still know very little about functioning of children with mild to moderate DSLD, their capabilities or weaknesses. The only treatment for them has been speech therapy. In many cases it takes more than a year to overcome DSLD, which arise the question: is this the best treatment possibility? Is it really only speech and language, what are impaired in these children? Some authors have proposed that DSLD is not usually an isolated, but rather a marker of overall neurodevelopmental disorder (Hill 1998, Alcock 2006) and there is interplay between language skill development and progress in the domains of motor, social, and cognitive skills (Shevell et al. 2005).

The expression "speech and language disorder" is generic and it could be divided into more specified subgroups. Unfortunately, in most of the studies the exact domain of disorder has remained unspecified and there are no particulars about differences between these subgroups.

The main goal of the present study was to identify the characteristic features of the motor performance, perception and social interaction abilities in children with mild to moderate DSLD, as well as to determine the differences between specified subtypes of speech disorders in assessed abilities.

2. REVIEW OF LITERATURE

2.1. Definition, subtypes and prevalence of developmental speech and language disorders

By definition, speech is the production of sounds; and language is the understanding and use of words to communicate with others. Disorders of speech and language may occur separately or jointly (Simms 2007). Developmental speech and language disorder (DSLD), also known as specific language impairment (SLI) is one of the most common subtypes of childhood developmental disability (Silva 1980, Webster et al. 2006, Newmeyer et al. 2007), affecting 4% to 14.6% of children (Tomblin et al. 1997, Shrieberg et al. 1999, Broomfield and Dodd 2004). Boys appear to be at somewhat increased risk for speech and language disorders compared with girls, with ratios vary from 1.3 to 5.9:1 in clinical samples (Shriberg and Kwiatkowski 1994, Tomblin et al. 1997, Broomfield and Dodd 2004, Grizzle and Simms 2009). It is defined as an isolated significant delay in the proper use of communicative expressive and/or receptive language in the absence of observed cognitive impairment, hearing loss, neurological disorders or abnormal social interactions (Bishop 1992, Leonard 1998, Nass 1999, Fernell et al. 2002, Grizzle and Simms 2009). However, the validity of DSLD has been questioned, since the existence of additional impairment is common (Locke 1998).

The clinical picture is quite varied; many children have speech as well as language disorders, others may have pure speech or pure language disorders (Bishop 2002, Fernell et al. 2002). Girls predominate in expressive-receptive problems, while boys predominate in expressive language and oral-motor problems (Selassie et al. 2005).

In case of isolated impairment of expressive language (IEL), children have normal nonverbal and receptive language ability but are limited in their ability to speak. Early symptoms include small vocabularies, use of short, incomplete sentences and production of confusing or disorganized conversations. Over time, it may become apparent that they have difficulty retrieving words and in formulating sentences (Leonard 1998, Johnson 2007, Grizzle and Simms 2009). But such a definition „disorder“ also calls into question, because these children may represent the lower end of the normal distribution of language skills, differing primarily in degree, rather than in kind, from their peers with typical language development (Dollaghan 2004).

The prevalence of IEL with exclusion of other disabilities in preschool children has been estimated as high as 7% to 36% (Tomblin et al. 1997, Horwitz et al. 2003, Broomfield and Dodd 2004, Selassie et al. 2005). Childhood language disorders are difficult to identify reliably in very young children (Dale et al. 2003). However, language disorders that are identified in the later preschool years show high rates of persistence (Law et al. 2000, Beitchman et al. 2001, Tomblin et al. 2003). Moreover, children with these language disorders are at high risk for long-term adverse outcomes, including reading and other academic difficulties (Young et al. 2002, Nathan et al. 2004), behavioral and social problems (Tomblin et al. 2000, Beitchman et al. 2001).

Speech sound disorder (SSD) is a developmental disorder characterized by speech production errors that significantly impact intelligibility (Shriberg 2003). Children with SSD may exhibit problems in learning to pronounce various speech sounds correctly. SSDs may be subdivided into two primary types: articulation disorders (AD) and phonological disorders. However, some may have a mixed disorder in which both articulation and phonological problems exist. AD is based on difficulty with motor production of the intended speech sounds with the main articulators (Bernthal and Bankson 1998). If no organic cause can be found, the probable cause of AD may be delayed maturation of psychomotor skills. AD can range in severity from mild to severe and children with mild AD usually have difficulty pronouncing a few consonant sounds past the age at which correct pronunciation is expected (Bauman-Waengler 2004, Grizzle and Simms 2009).

In a phonological disorder the child is having trouble learning the sound system of the language, failing to recognize which sounds contrasts contrast meaning. Though phonemic disorders are often considered language disorders in that it is the language system that is affected, they are also SSD in that the errors relate to use of phonemes. This makes them different from usual DSLD, which is primarily a disorder of the grammar and usage of language rather than the sound system (Bowen 2009). Although the terms phonological disorder and SSD refer to the same constellation of clinical signs, the term SSD is currently preferred because it recognizes that the disorder may have antecedents in both articulatory (sensorimotor) and phonological (cognitive-linguistic) domains. However, SSD do not usually have an identifiable cause, such as sensory (e.g. hearing), structural (e.g. cleft palate) or neurological (e.g. cerebral palsy) problems. Children with SSD show a slowed rate of speech acquisition, but often follow a relatively typical sequence of sound development (Shriberg and Kwiatkowski 1994). Shriberg et al. (1999) reported the prevalence of 3.8% for SSDs in 6-year-old children and the extent to which SSDs co-occurred with language disorders only of 0.5%. SSD may resolve spontaneously over time (Shriberg and Kwiatkowski 1994), long-term persistence and negative sequences are not as common as for language disorders (Johnson et al. 1999). However, mild, residual speech problems may have subtle, negative effects on listener's perceptions of an individual's overall competence (Hall 1991, Silverman 1992). Some children with SSD may also be at risk for reading and other academic difficulties (Lewis et al. 2000, Raitano et al. 2004).

2.2. Motor performance in children with and without developmental speech and language disorders

Muscle force-generation and relaxation capacity in children

The term 'muscular strength' refers to a measure describing an individual's ability to exert maximum muscular force statically or dynamically (Osternig 1986). Force-generation capacity of the skeletal muscles is an important indicator of neuromuscular performance which changes throughout the years of growth and maturation. Muscle strength is directly related to functional performance and it is essential for performing many different daily activities (Kramer and MacPhail 1994, Damiano and Abel 1996, Tervo et al. 2002).

In pediatrics, muscle strength characteristics have been usually evaluated by the measurement of static (isometric) hand-grip strength and by dynamic forces derived from jumping (Fricke and Schoenau 2005, De Ste Croix 2007). Accordingly, numerous studies in this field have focused on measuring the maximal isometric strength, which gives information about the maximal voluntary force-generation capacity of the muscles, and vertical jumping performance, which provides information about the explosive force production (power output) of the leg extensor (LE) muscles. The development of muscular strength and power in children is related to factors such as age (Beunen et al. 1992, De Ste Croix et al. 1999, Martin et al. 2000, Neu et al. 2002, Molenaar et al. 2010), body mass (Beunen et al. 1992, De Ste Croix et al. 1999), muscle mass or cross-sectional area (Kanehisa et al. 1995, Martin et al. 2000, Fukunaga et al. 2001, Runge et al. 2004), and neural maturation (Housh et al. 1996, De Ste Croix et al. 1999). Davies et al. (1983) and Davies (1985) found that MVC force and half relaxation time (HRT) were significantly different in children at different ages, whereas younger children demonstrated lesser maximal strength and longer HRT. However, if standardization was made for an anthropometric estimate of muscle cross-sectional area, the differences in strength disappeared. They concluded that absolute differences in muscle strength in children are a function of muscle mass. Similar results were obtained in the study of Lin et al. (1994) and by Morse et al. (2008) who showed that child's muscles are initially slow to relax but relaxation doubles in speed up to adult rates by early adolescence.

However, the age-related differences in muscle strength cannot solely be explained by differences in body size or muscle mass (Martin et al. 2000, De Ste Croix et al. 2003, Korff et al. 2009). Muscle strength is dependent on neuromuscular determinants as agonist muscle activation and antagonist muscle coactivation (Ikeda et al. 1998, Maganaris et al. 2001, Stackhause et al. 2005). Impairment of the central nervous system may influence the generation of muscle force even in the absence of muscle atrophy, because the skills of coordinating muscular activity are diminished (Fricke and Schoenau 2005). The recruitment of muscle fibres by the nervous system (Ramsay et al. 1990, Fricke and Schoenau 2005, Streckis et al. 2007, Falk et al. 2009) and myelination of the motor nerves (Brooks and Fahey 1985, Haywood 1993, De Ste Croix et al. 1999) are also major factors for the contraction force and contraction speed of the muscles. Level of motor unit activation as well as myelination is both influenced by the development of the central nervous system. Blimkie (1989) has found that 16-year-old boys could voluntarily activate a greater percentage of their available motor units during a maximal voluntary contraction than 11-year-old boys.

It is known that prepubertal boys and girls develop with about the same rate of growth in stature and mass. Most of the studies, investigating maximal voluntary strength and time-course characteristics in children, indicated no significant differences between prepubertal boys and girls (Seger and Thorstensson 1994, Kanehisa et al. 1995, Seger and Thorstensson 2000, Pääsuke et al. 2003). However, an observation that boys exceed girls in maximal voluntary muscle strength (Raudsepp and Pääsuke 1995, Molenaar et al. 2010) prior to puberty has also been published. The recent study of Molenaar and colleagues (2010) confirmed that hand-grip strength of 4–6-year-old boys is as much as 24% to 34% stronger than in girls.

Successful performance of vertical jump is conditioned by the ability of maximum muscular power production, which is a function of force and velocity (Korff et al. 2009). Dynamic force of the knee extensor muscles is one important factor limiting performance in jumping exercises. Another important factor in performing the jump is intramuscular coordination and coactivation of the agonist-antagonist muscles involved (Rack and Westbury 1974, Hortobàgyi and DeVita 2000, Van Praagh and Doré 2002, Fricke and Schoenau 2005). According to Jensen et al. (1994) children demonstrate a reduced ability to control intersegmental movements during vertical jumping. On the contrary, Korff and his colleagues (2009) found in their study that during hopping children can coordinate their limbs appropriately.

Unfortunately, there is missing data concerning muscle strength and contractile properties in children with DSLD.

Fine- and gross-motor performance in children with developmental speech and language disorders

Motor control development has long been associated with the level of language skills (Alcock 2006), because speech production is highly skilled behaviour that requires rapid and coordinated movements of the orofacial articulators and it is governed by similar principles of motor development and learning (Maas et al. 2008). A few studies have shown that motor performance can affect language (Gentilucci et al. 2004, Pulvermüller et al. 2005). Pulvermüller et al. (2005) demonstrated that the left hemisphere's cortical systems for language and action are interlinked and that activation in motor areas can influence the processing of words semantically related to arm and leg movements. And vice versa, the study of Flöel et al. (2003) found that speech causes an automatic activation of the motor processes involved in gestures. According to Thal et al. (1997), children who are late in onset of both spontaneous communicative gesture and spoken language are more likely to remain delayed compared to those, whose speech is delayed but who start making communicative gestures at a typical age. In addition, children with DSLD have shown to demonstrate gestures what are similar to younger peers (Hill 1998). However, the data characterizing motor abilities in children with DSLD are still incomplete and controversial.

There is increasing evidence that children with DSLD experience a broader range of difficulties and motor impairment is a common co-morbidity in children with DSLD (Sommers 1988, Powell and Bishop 1992, Reeves 1995, Bradford and Dodd 1996, Hill 1998, Rintala et al. 1998, Chow and Henderson 2003, Rintala and Linjala 2003, Webster et al. 2006, Visscher et al. 2007, Cheng et al. 2009). Gaines and Missiuna (2007) showed very high prevalence of motor coordination difficulties in children with DSLD. Dyck et al. (2006) found a strong correlation between expressive- and receptive-language abilities and fine- and gross-motor abilities in autistic children. Comprehensive literature review of 28 different studies by Hill (2001) and the meta-analysis of 16 different studies by Rechetnikov and Maitra (2009) confirmed association between speech-language and motor impairments. The prevalence of motor difficulties in children with DSLD has been estimated to vary from about 50% up to 90% (Rintala et al. 1998, Fernell et al. 2002, Estil et al. 2003, Shevell et al. 2005, Webster et al. 2005, Visscher et al. 2007). Moreover, speech and language disorders have been claimed to affect motor performance differently. Combined speech and language disorders seem to have more impact on motor performance than only language disorders, and when speech production is affected, motor problems appear to be more pronounced (Bishop 2002, Visscher et al. 2007). Among children with DSLD, motor impairment has been found to correlate most strongly with the observed severity of the child's disorder. Consistent with this, in studies that have recruited children with greater degrees of DSLD, a higher incidence of motor impairments has been reported (Robinson 1991, Tannoc and Brown 2000).

Majority of studies assessing motor performance in children with DSLD have focused on oral-motor or fine-motor skills and found them to be impaired (Bishop and Edmundson 1987, Ettala-Ylitalo and Laine 1991, Helzer et al. 1996, Trauner et al. 2000, Hill 2001, Bishop 2002, Alcock 2006, Goozée et al. 2007, Newmeyer et al. 2007, Terband et al. 2010). The co-occurrence of oral-motor problems in children with DSLD has been estimated to 57%, while boys predominate in oral-motor dysfunction (Ettala-Ylitalo and Laine 1991, Selassie et al. 2005). Fine-motor impairments occur approximately in 35% to 41% of children with DSLD (Trauner et al. 2000, Webster et al. 2005).

Study of Alcock (2006) revealed that language and oral-motor skills are linked in normal development. Even if some children have cognitive skills in the typical range, poor oral-motor function could lead to poor speech and language skills. Stark and Blackwell (1997) confirmed that oral-motor skills were associated with both nonword repetition and phoneme identification in children with DSLD. Oral movements and coordination of articulators in children with AD have found to be aberrant compared to control children (Goozée et al. 2007) and these children have more clinical signs and symptoms of functional disturbances of the oral-motor system (Ettala-Ylitalo and Laine 1991).

Scientists have pointed out that there is an association between abnormal oral-motor function and visual-motor performance, suggesting an underlying abnormality in the planning and processing of motor movements that affect both speech and fine-motor performance (Preis et al. 1995, Bishop 2002, Newmeyer et al. 2007). A number of studies have confirmed that children with DSLD are significantly slower and/or more inaccurate than regular children in motor hand function (Carroll et al. 1989, Powell and Bishop 1992, Preis et al. 1995, Owen and McKinlay 1997, Leonard 1998, Bishop 2002, Ozcebe et al. 2009). Studies of Preis and colleagues (1997) and Hill (2001) indicated that results of fine-motor skills such as peg moving, bead threading, finger tapping and finger opposition were considerably poorer in children with DSLD compared to normative sample. Children with DSLD perform also below average for age in tasks requiring grasping, object manipulation, and eye-hand coordination (Newmeyer et al. 2007). Preis and colleagues (1995) argued that even subgroup of DSLD children with a grammatical type of impairment without significant articulatory (motor) deficits, were impaired in the performance of complex fine-motor skills. Furthermore, investigations of central timing deficits and response time in children with DSLD (Miller et al. 2006, Peter and Stoel-Gammon 2008) have confirmed lower timing accuracy, expressed in the oral and the limb modality, as well as slow response time in motor and nonverbal cognitive domains. Miller et al. (2001, 2006) concluded that speed of processing in children with DSLD is generally slower that of children with normal language. However, some children with DSLD do not appear to show the deficits of this type.

Although, when oral-motor and fine-motor skills are linked to language development, gross-motor skills have found not to correlate with language (Alcock 2006). Cheng et al. (2009) demonstrated that manual dexterity, but not ball skills or balance measured by M-ABC is predictive of scores on the speech and language tests and emphasized that manual dexterity seems to be an important clue for understanding the shared mechanism of motor disorder and DSLD.

Controversially, Webster and colleagues (2005) examined the relationship between language development and motor function and reported that 36% of children with DSLD have gross-motor impairments and 24% showed evidence of both fine- and gross-motor impairments. Similarly, in the study of Zelaznik and Goffman (2010), children with DSLD showed poorer performance on both gross- and fine-motor skills compared to their normally developing peers. However, timing skill in the manual domain was equivalent to that seen in controls.

For gross-motor performance, it has been observed that skills like static balance, stepping, running, hopping on one leg, toe gait, heel gait, stair-climbing, muscle tone, and ball-skills of children with DSLD were poor relative to normal children (Powell and Bishop 1992, Rintala et al. 1998, Noterdaeme et al. 2002, Visscher et al. 2007, Webster et al. 2006). Moreover, balancing on one leg proved to be one of the most discriminating measures between children with DSLD and normal sample (Powell and Bishop 1992, Visscher et al. 2007). Estil and colleagues (2003) pointed out that motor problems in language impaired children are not general, but rather restricted. They demonstrated that children with expressive oral language problems differed from controls only in bimanual coordination and static balance. In contrast, other authors have found no difference between children with DSLD and regular children in balance tasks (Stark and Tallal 1981, Cheng et al. 2009). A recent study of Visscher and his colleagues (2010) revealed that children with DSLD score lower on all the locomotor and object control tests compared with their typically developing peers. Furthermore, children with language disorder only performed better than children with isolated speech disorder or combined one. Although the performance of children with DSLD improves with increasing age, it lags behind that of typically developing children.

It is still unclear whether motor impairment in children with DSLD is the result of a more global developmental impairment or reflects a biological function that has greater effects on language and motor function than nonverbal cognition (Webster 2006). Some authors (Ettala-Ylitalo and Laine 1991, Hill 1998, Willinger et al. 2003, Shevell et al. 2005) have hypothesized that neurodevelopmental immaturity or later maturing of neuromuscular control in the child might be the explanation for DSLD as well as motor impairments. This suggestion is in line with the study results of Hetrick and Sommers (1988), who found that children with AD performed more poorly in bisensory tasks indicating immaturity of central nervous system; and by the longitudinal study of Le Normand et al. (2000) showing that the progression of motor control of language follows a parallel course to neuromotor development. Investigation data of Coplan (1985) and Shevell et al. (2005) supported the concept of specific language delay as a marker for a later increased risk of more wide-ranging neurodevelopmental difficulties and not merely reflecting a maturational lag. In accordance with the suggestions of previous authors, it has been verified that substantial proportion of children with DSLD has additionally neurodevelopmental problems (Buschmann et al. 2008). Studies of Cermak et al. (1986) and Sommers (1988) revealed that children with AD have more motor coordination problems and soft neurological signs than the typically developing peers. Researchers have theorized that common underpinnings between speech disorders and motor difficulties may include problems with praxis (Dewey 1993, Hall 2000), which is a deficit in motor movements and sequencing in the absence of basic sensory or motor impairments; cerebellar mediation deficits (Ivry and Diener 1991, Diamond 2000, Ullman and Pierpont 2005); inter-hemispheric information transfer problems (Sigmundsson et al. 1999, Estil et al. 2003); or a more diffuse atypical brain development (Kaplan et al. 1998). Ivry and his colleagues (Ivry and Keele 1989, Ivry and Diener 1991) have suggested the possibility of a breakdown in the control of the temporal coupling of signals within the cerebellum. This hypothesis is given credence by the work of Fawcett and Nicolson (1995, 1999) in their work with phonological dyslexics, a deficit that is closely related to phonological language impairment (Plaza 1997); which demonstrated dyslexics to be impaired on static balance and number of fine-motor tasks associated with cerebellar function. A study using positron emission tomography (Jueptner et al. 1996) showed that the cerebellum and some extent basal ganglia were activated during a visually guided tracking task similar to drawing. Also other researchers (Ullman and Pierpont 2005, Visser and Bloem 2005) suggested that motor deficits in speech disordered children appear from a dysfunction of basal ganglia circuits or the cerebellum, causing impairments of sequencing, speed, timing, and balance. In throwing a ball, the timing, amplitude and velocity of finger opening is under the control of cerebellum (Timmann et al. 1999). Similarly, in catching a ball, the basal ganglia coordinate the duration of the reach and approach of the ball (Bulloc 2004). Interestingly, a disturbance in language production and speech initiation could be viewed as a consequence of a disturbed function of the left basal ganglia (Fabbro et al. 1996).

Visscher et al. (2007) have suggested that diversity in the outcomes in the great majority of studies estimating children with speech and language disorders may be the result of the different neural circuits in which brain structures participate. Because of the marked segregation and specificity of inputs and outputs of brain structures, dysfunctions of slightly different parts of a specific brain structure may express themselves in different ways in subgroups of children with DSLD. According to the atypical brain development framework, developmental variation in brain structures and functions leads to variation in abilities underscoring the interrelatedness of developmental disorders (Kaplan et al. 2006).

2.3. Haptic perception in children with and without developmental speech and language disorders

The "haptic system" is a distinctive perceptual system, oriented towards discriminating and recognizing objects by handling those (McLinden and McCall 2002). To recognize the properties of physical objects and build a mental representation of them is a prerequisite for the acquisition of words referring to objects (Kiesel-Himmel 2008). Experiments with infants show that even at a very young age infants possess a concept of objects – long before they know the corresponding words (Spelke et al. 1992, Baillargeon 1993).

Oral haptic skills seem to be substantial in speech production (Hetrick and Sommers 1988, Fucci et al. 1992) and somatosensory feedback plays an essential role in controlling speech production. Children whose oral haptic system is dysfunctional are likely to have difficulty learning oral-motor skills like articulation, because they do not receive adequate information from their receptors. Schliesser and Cary (1973) hypothesized that deviations in articulation may be associated with poorer oral stereognosis. This hypothesis was supported by the study of Speirs and Maktabi (1990), who confirmed that children with DSLD have lower scores of oral stereognosis.

Hill (2001) suggested in consideration of poor fine-motor skills in children with DSLD that they have in addition to motor difficulties also perception deficits. The information from manual exploration differs depending on whether a child experiences the physical world passively tactile (passive touch, without any muscular effort) or through action (active or dynamic touch, obtaining not only cutaneous but also proprioceptive information from receptors in muscles, tendons and joints) (Kiesel-Himmel 2008). Exploratory skills increase with maturation and with practice. Through the use of different stereotypical hand movement patterns or exploratory procedures (EPs), the child can perceive a variety of object characteristics, such as substance object properties (temperature, texture, weight determined by density), structural properties (volume, global shape, exact shape, weight determined by volume) as well as functional properties (motion of a part of the object or specialized function) (Kiesel-Himmel 2008). Humans are identified to be highly systematic in their manual exploration strategies (Lederman and Klatzky 1987). If detailed information about a particular property is desired, then a person will select the EPs that provide the most precise information about that property.

The development of haptic recognition appears to be dictated by the motor capabilities needed to perform EPs and followed by cognitive considerations, but already preschool-aged children use appropriate haptic EPs, as has been found with adults (Buschnell and Boudreau 1991, 1993). Kalagher and Jones (2011) claimed that younger children's difficulties with haptic recognition appeared to stem from their failure to use their hands to obtain reliable haptic information about objects. Older children are not only able to recognize more objects and to do so more quickly, but also are more thorough in their exploration patterns (Morrongiello et al. 1994).

Haptic object-recognition (HOR) involves in addition to the perception of different characteristics of an object by touch also cross-modal transfer to create a visual image from the perceived object (Berryman et al. 2006). This cross-modal haptico-visual transfer ability increase with age (Stilwell and Cermak 1995, Bushnell and Baxt 1999) and in 5-year-old children, cross-modal haptico-visual transfer ability is nearly perfect with familiar three-dimensional objects (Klatzky et al. 1985, Klatzky et al. 1989, Klatzky and Lederman 1993, Buschnell and Baxt 1999).

Information about manual haptic object-recognition in children with DSLD is more heterogeneous compared to data about oral stereognosis. In haptic recognition, children with DSLD have been shown to perform more poorly than their normally developing peers (Kamhi et al. 1984, Montgomery 1993, Accardi 1997, Giannopulu et al. 2008). Study of Giannopulu et al. (2008) revealed that bimanual haptico-visual recognition task is correlated to linguistic and non-linguistic cognitive performances in preschoolers. Similarly, significant correlation has been found between haptic perception and expressive vocabulary size in language-impaired children (Kiesel-Himmel 2008). Kiesel-Himmel (2008) also pointed out that children who experience difficulties with language acquisition might be expected to manifest a deficit in non-linguistic forms of representation or inadequate EPs. Majority of studies, which have found children with DSLD to make more recognition errors, children had to select a picture corresponding to the mental image of the just-felt shape (Montgomery 1993). However, Montgomery (1993) emphasized that children with DSLD performed comparably with their normal language peers in test where only a simple tactile similarity judgement had to be made. This finding suggests that children with DSLD are not deficient in their non-linguistic representational abilities as measured by haptic recognition. Also Accardi (1997) noted that preschool children with and without DSLD do not differ for proprioceptive ability, but significant relationship exists between imagination as one aspect of proprioceptive ability and conceptual learning. It is possible that children with DSLD experience difficulties especially in tests that require different cognitive capabilities, for example tactile short term memory in addition to simple perception (Kiesel-Himmel 2008).

Interestingly, some authors (Penhune et al. 1998, Ullman and Pierpont 2005) have demonstrated that basal ganglia's role in performing skills involving sensorimotor sequences like in tasks of haptic object recognition, is especially important.

2.4. Social abilities in children with developmental speech and language disorders

Communication is acknowledged to be a central element in an individual's health and well-being and is critical to emotional, cognitive and social functioning (Vitkovitch 2008). Language competency is necessary for the application of social communication skills and for the initiation and maintenance of such relationships (Marton et al. 2005). Children with DSLD are at a disadvantage in forming successful peer relationships, and therefore, at risk for social problems and poorer self-esteem (Skinner and Piek 2001, Jerome et al. 2002, Marton et al. 2005). Accordingly, several studies have demonstrated that disorders in either speech or language can have significant negative effects on a child's social and emotional functioning, including an increased risk for anxiety, depression, social isolation, or attention problems (Beitchman et al. 1996, Irwin et al. 2002, Horwitz et al. 2003, Willinger 2003, Hart et al. 2004, Clegg et al. 2005, Shevell et al. 2005, Russell 2007). A higher frequency of later behavioural and social difficulties was documented also in children with DSLD even when language skills effectively returned to normal (Paul et al. 1991).

Study of Snowling et al. (2006) demonstrated that different language profiles were associated with different social difficulties and behavioural disorders suggesting that factors other than general immaturity are at play in determining different outcomes in children with speech-language disorders. Children with specific receptive and expressive language impairment had more social difficulties than children with only expressive language impairment who showed more attention deficits. Beitchman et al. (1996) confirmed the finding that children without receptive language problems show superior social adjustment. Significant differences in social competence were also found (Farmer 2000) between the typically developing children and children with DSLD who attended the special schools, but not between normative sample and children with DSLD from integrated placements. Redmond and Rice (1998) argued that children with language disorders have to adapt to a social environment in which they cannot communicate well and are often not understood, and as a consequence, they develop social difficulties that are more marked in the school context than in the home environment.

Children with DSLD are less preferred playmates as compared to typically developing peers and are often the subject of peer rejection (Fujiki et al. 1999). They are more likely to initiate conversations with adults than with their peers (Rice et al. 1991). However, the language deficits alone do not account for the range of social difficulties that children with DSLD encounter (Brinton et al. 1998, Singer and Bashir 1999, Marton et al. 2005). Motor competence is important prerequisite for the participation in normal sporting and playground activities (e.g. ball games, running, and climbing). Webster and colleague's (2005) findings indicated that communication scores as measured by the Battelle Developmental Inventory, correlated strongly with both fine-motor and gross-motor scores. Despite the range of impairments seen in children with DSLD, it is unclear whether these deficits are secondary to the effects over time of the underlying communication disorder or whether they are separate but intrinsic part of the underlying disorder that leads to language impairment. As such, it is possible that co-morbid motor impairments exacerbate the social isolation commonly seen in children with DSLD (Webster et al. 2006).

In conclusion, the analysis of literature reveals that although DSLD is defined as an isolated delay, children with DSLD demonstrate impairments also in other areas of development. The majority of studies investigating children with DSLD have recruited subjects with persisting moderate or severe speech and language disorders from clinics or special schools (Fernell et al. 2002, Webster et al. 2006, Newmeyer et al. 2007, Visscher et al. 2007). There is insufficient data about sensorimotor or social functioning in children with mild or moderate DSLD in preschool-age. Moreover, few of these studies (Visscher et al. 2007) have compared children with different profile of speech and language disorders. Data about force-generation and relaxation capacity in children with DSLD is missing.

3. OBJECTIVES OF THE STUDY

The general aim of the present study was to identify the characteristic features of sensorimotor and social functioning in preschool children with mild to moderate developmental speech and language disorders in comparison of healthy peers and considering the type of DSLD.

The specific objectives were:

(1) To evaluate force-generation and relaxation capacity of the skeletal muscles, vertical jumping performance, eye-hand coordination and functional motor performance (Papers I-III).

(2) To measure haptic perception (Paper II-III).

(3) To assess social interaction abilities (Paper III).

4. MATERIALS AND METHODS

4.1. Subjects

Ninety-three children with developmental speech and language disorders aged 4–6 years and 78 age- and gender matched children with typical development as controls participated in this study. Table 1 demonstrates the division of the subjects by the results of language tests, their mean age and anthropometric characteristics in different studies.

Table 1. Descriptive data (mean±SE) of the subjects.

Papers	N	Age (months)	Height (cm)	BM (kg)	BMI ($kg \cdot m^{-2}$)
Paper I					
Boys with mild/moderate DSLD	20	65±2	112.4±1.4	19.5±0.5	15.4±0.3
Boys of CG	21	67±1	113.5±0.8	20.2±0.5	15.7±0.2
Girls with mild/moderate DSLD	12	67±2	111.4±1.6	19.9±0.8	16.0±0.4
Girls of CG	24	66±1	116.1±0.8†	21.6±0.5•	16.0±0.3
Paper II					
Boys with mild/moderate IEL	28	67±1	116.2±1.1	22.4±0.8	16.5±0.4
Boys of CG	26	66±1	113.5±1.1	21.6±0.9	16.7±0.4
Paper III					
Children with mild IEL	29	66±1	115.7±1.1	22.2±0.7	16.5±0.4
Children with mild AD	27	66±1	116.2±0.8	22.0±0.5	16.3±0.3
Children of CG	30	66±1	113.9±0.9	21.6±0.8	16.6±0.4

DSLD = developmental speech and language disorders; CG = control group; IEL = impairment of expressive language; AD = articulation disorders; BM = body mass; BMI = body mass index.
†$p<0.05$ compared to other measured groups.
•$p<0.05$ compared to boys with DSLD and CG boys.

Measurement of language skills is presented in chapter 4.3.1. Relying on the results of language tests, children were distributed into different subgroups:

In Paper I: boys with mild to moderate DSLD (age range 4 years and 6 months to 6 years and 7 months), girls with mild to moderate DSLD (age range 4 years and 5 months to 6 years 10 months), control group boys (age range 4 years and 11 months to 6 years) and control group girls (age range 4 years and 11 months to 6 years and 2 months) with typical language development.

In Paper II: boys with mild to moderate impairment of expressive language (age range 4 years and 11 months to 6 years and 5 months) and age-matched boys (age range 4 years and 8 months to 6 years and 4 months) with typical language development.

In Paper III: children with mild impairment of expressive language (23 boys and 6 girls; age range 4 years and 11 months to 6 years and 5 months); children with mild articulation disorders (20 boys and 7 girls; age range 4 years and 11 months to 6 years and 1 month) and children with typical language development (23 boys and 7 girls; age range 5 years to 6 years and 1 month).

Exclusion criteria were: (1) combination of expressive-receptive language problems; (2) receptive language disorders; (3) occurrence of other health-related conditions like mental and physical disabilities, hearing, autistic spectrum or neurologic disorders. All children who participated in our study were confirmed to be developing adequately (except in the area of speech and language development in children with DSLD) by kindergarten paediatricians, who regularly assess children for different developmental aspects. No child had an intelligence quotient <80 and all speech-disordered children were able to learn of the same level with their peers. Controls were all healthy and typically developing children from the same kindergartens as the children with DSLD.

The study carried the approval of the University Ethics Committee. Written informed consent from the children's parents and the child's assent were necessary preconditions for participation in this study.

4.2. Study design

The present study was carried out in 2003–2004 and in 2009–2010. All participants were recruited from ordinary public kindergartens of Tartu, Estonia. Organizers of the study excluded the recruitment of children from special squads or kindergartens for children with severe speech and language disorders or problems in their mental or physical development. Measurements were performed partly at the kindergartens and partly at the Laboratory of Kinesiology and Biomechanics, University of Tartu. All assessments were carried out in the mornings to minimize possibility of fatigue. All language tests, motor performance and haptic object-recognition assessments were performed individually, by appropriately qualified therapists, who were blinded to the children's group assignment. Subjects were given instructions before data collection and the testing procedures were demonstrated. This was followed by practice session to familiarize the subjects with the procedures.

4.3. Methods

4.3.1. Measurement of language skills

The measurement of language skills was carried out to determine the existence, type and severity of DSLD for distribution of subjects into subgroups. The production and comprehension of language was assessed by the *Reynell Developmental Language Scales,* third edition (RDLS-III) and *Boehm Test of*

Basic Concepts, third edition-Preschool (Boehm-3 Preschool) administered by professional speech-language pathologists from the Children's Clinic of Tartu University Hospital.

The RDLS-III (Reynell and Gruber 1990) are individually administered tests of verbal comprehension and expressive language skills for young children from 18 months to 7 years. The RDLS-III reflects the developmental progression of normal child language, focusing on features which are known to distinguish language-impaired children from language-normal children (Edwards et al. 1999). Boehm-3 Preschool (Boehm 2008) is an individually administered assessment tool designed to evaluate young children's underestanding of the basic relational concepts important for language and cognitive development.

A deviation in the range of ≥1 to 2 SD below the age standards in language tests was used as cut-off for mild to moderate speech-language impairments (Paper I–II) and a deviation in the range of ≥1 to 1.5 SD below the age standards as cut-off for mild speech-language impairments (Paper III).

4.3.2. Measurement of muscle force-generation capacity

Measurement of force-generation and relaxation capacity of the leg extensor muscles

During measurement of maximal isometric strength of the LE muscles (Paper I) the subjects were seated on a custom-made dynamometric chair in a horizontal frame with knee and hip angles equal to 110° and 120°, respectively (Figure 1). The feet were placed on a footplate mounted on a steel bar held in ball-bearings on the frame. The participants were instructed to push the footplate as forcefully as possible for 2–3 s in three cases: (1) unilateral contraction of the right leg (UL_{right}), (2) unilateral contraction of the left leg (UL_{left}) and (3) bilateral contraction (BL) in random order. Three trials were performed for each case and the greatest strength value was taken as the maximal isometric strength. A rest period of 2 min was allowed between the trials.

Capacity for rapid isometric voluntary force-generation and relaxation of the LE muscles (Paper II) was measured during bilateral contraction. The subjects were instructed to react to visual stimuli (lighting of the signal lamp) as quickly and forcefully as possible by pushing the footplate, to maintain the maximal effort as long as the signal lamp was on (2 s) and to relax the muscles suddenly after the disappearance of the signal. Three attempts were carried out, and a rest period of 2 min was allowed between the attempts. The following characteristics were calculated: latency of contraction (LAT_c) – the time delay between the visual signal and the onset of force-generation; rate of force development (RFD_{50}) – the first derivate of force development at the level of 50% of MVC; MVC force of the LE muscles (MVC); latency of relaxation (LAT_r) – the time delay between the visual signal stopping and onset of quick decline in force-generation; and half-relaxation time (HRT) – the time of half of the decline in force during relaxation. Raudsepp and Pääsuke (1995) demonstrated significant test-retest correlations in the measurement of isometric MVC force of the LE muscles in children using this dynamometer (r=0.84–0.92 in boys and r=0.81–0.90 in girls), indicating an acceptable test-retest reliability.

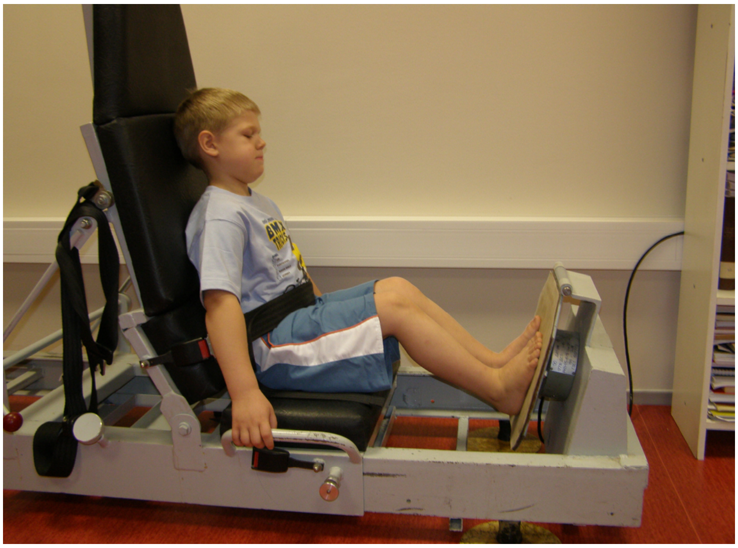

Figure 1. Experimental setup for the measurement of isometric strength characteristics of the leg extensor muscles.

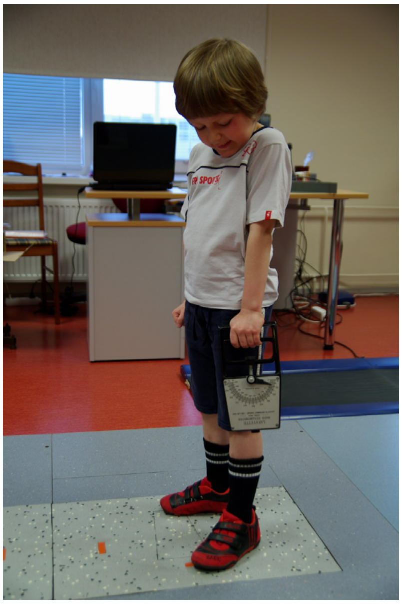

Figure 2. Measurement of hand-grip strength.

Measurement of hand-grip strength

Maximal isometric hand-grip strength (Paper I) was determined with standard mechanical hand-dynamometer (Lafayette, USA). The test was performed with dominant hand in standing position, hand held unbent on the side (Figure 2). The dominant hand of the children was determined with simple drawing task. The subjects were instructed to squeeze the handle as forcefully as possible for 2–3 s. Three maximal efforts were performed and the value of the strongest squeeze was recorded as maximal isometric hand-grip strength (UL_{grip}). A rest period of 2 min was allowed between the squeezes. According to van den Beld et al. (2006), the validity of the hand dynamometer in children aged 4–11 years is good (r=0.78–0.82) and reproducibility is high (ICCs 0.91–0.93).

Figure 3. Measurement of vertical jumping performance.

Measurement of vertical jumping performance

The vertical jumping test (Paper I) was performed on force platform (Kistler 9286A, Switzerland) with the dimensions of 0.40x0.60 m and natural frequency of 500 Hz. The subjects were instructed to jump as high as possible with their hands on the hips (Figure 3). The following characteristics were recorded by a vertical force-time curve for each jump:

(1) jumping height (CMJ_{height}) by the height of the body centre of gravity:

$$H = g\, t_f^2 / 8,$$

where g is acceleration of gravity (9.81 m/s^2) and t_f flight time.

(2) peak vertical ground reaction force (CMJ_{force}).

Each subject performed three maximal jumps and the highest jump was used for further analysis. A rest period of 2 min was allowed between the jumps.

4.3.3. Measurement of functional motor performance

Minnesota Manual Dexterity Test (MMDT)

MMDT was used to measure eye-hand coordination of the subjects (Paper I). The test was performed individually, in standing position behind the table with suitable height for the child (the height of a child's navel point). The subjects had to turn over and displace little disks on the holes of pegboard as fast as possible. The test was first carried on bilaterally, then unilaterally with the dominant hand. In both cases children performed three trials and the fastest result was recorded. The test-retest reliability (ICCs of 0.79–0.87) and the validity (r=0.85–0.95) of the MMDT is acceptable to high (Desrosiers et al. 1997).

Movement Assessment Battery for Children (M-ABC)

For measurement of functional motor performance (Paper II–III) the M-ABC was used. M-ABC is a formalized standardized test to identify children with motor problems. This test battery consists of 8 subtests in one age-band: 3 tests of manual directory, 2 tests of ball skills, and 3 tests of static and dynamic balance (Henderson and Sugden 1992). Each subtest is scored on a scale from 0 to 5: score 0 is obtained for faultless performance, score 5 in case of failure. Summing the item scores of the 8 subtests generates an age-standardized impairment score (IS) from which a child's percentile can be calculated. High IS and low percentile indicate poor motor performance. Children scoring below the 5^{th} percentile on the M-ABC were considered to have definite motor impairment, whereas children scoring between 5^{th} and 15^{th} percentile were considered to have a borderline motor difficulties. The test has acceptable validity and reliability. Test-retest reliability is 0.75 and validity is 0.96 across items (Henderson and Sugden 1992, Chow and Henderson 2003).

4.3.4. Measurement of haptic perception

Haptic perception was measured by haptic object-recognition task (Paper II–III), where 5 common objects of daily living (key, toothbrush, teaspoon, pencil, and clothes-peg) were put into the bag. The subjects did not know in advance which items are in the bag. The child was instructed to put his/her hand into the bag, take one thing at a time, feel it, and guess what it is without visual stimuli. After answering the subject was allowed to take the item out of the bag. If the child gave a correct answer within 5 s, he/she was scored 0. If he/she gave an answer after 5 s, he/she was scored 1. The child was scored 2 when he/she gave at first wrong answer but corrected himself/herself within 3 s; and 3 if he/she gave wrong answer without correction. To eliminate the influence of vocabulary deficiencies, the examiner instructed subjects to name the item or to tell for what it is used for. If the child could not name the item but said for what he/she can use it, or when the answer was not grammatically accurate but comprehensible, the answer was counted correct. Summing the 5 item scores formed the test score. High scores indicate poor haptic perception.

4.3.5. Measurement of social interaction abilities

To evaluate child's social interaction (Paper III) with non-family member peers and adults, original questionnaire for kindergarten teachers was used. The questionnaire was completed by 2 separate teachers. Questions covered comprehensibility of child's spoken language by peers and adults; existence of habitual playmates and participation in spontaneous social or sporting games. Teachers rated the extent to which they agreed or disagreed with each statement on a 4-point likert scale. Summing the scores of the questions and calculation of arithmetical mean of questionnaires completed by two teachers produced a profile of the child's social performance. Lower scores represented higher level of social interaction (SI).

4.4. Statistical evaluation of the data

Standard statistical methods were used to calculate the means and standard errors of the mean (±SE). One-way analysis of variance (ANOVA) following by Tukey *post hoc* comparisons were used to test for differences between groups of children (Paper I–III). A level of $p<0.05$ was selected to indicate statistical significance (Paper I–III).

5. RESULTS

5.1. Muscle force-generation capacity

Force-generation and relaxation capacity of the leg extensor muscles

Mean values of isometric maximal voluntary strength of the LE muscles in measured groups are presented in Table 2. Girls with mild to moderate DSLD had lower ($p<0.01$) unilateral MVC force of the left and right LE muscles compared to boys with DSLD and CG children. Bilateral MVC force of the LE muscles was also less in girls with DSLD compared to boys with DSLD ($p<0.01$) and CG boys ($p<0.05$). Differences in unilateral and bilateral MVC force of the LE muscles between boys with mild to moderate DSLD and CG children were not significant ($p>0.05$).

Comparison of two groups of boys in Paper II revealed no significant differences ($p>0.05$) in the isometric force-time and relaxation-time characteristics (LAT_c and LAT_r) as well as in muscle relaxation capacity (HRT) between boys with mild to moderate IEL and controls (Table 3). However, boys with IEL had significantly lower ($p<0.05$) isometric MVC force and RFD_{50} of LE muscles compared to controls.

Table 2. Mean (±SE) values of maximal isometric strength in measured groups.

Paper I	UL_{right} (N)	UL_{left} (N)	BL (N)	UL_{grip} (N)
DSLD boys	274.2±21.3	270.6±21.9	500.9±21.7••	99.1±6.9*
CG boys	263.4±18.4	275.5±20.8	465.9±30.1	120.7±4.9
DSLD girls	177.8±24.5††	175.9±28.4††	359.3±36.8*	77.5±8.8***
CG girls	283.6±30.6	264.8±25.9	449.3±48.4	91.2±4.9**

UL_{right} = unilateral maximal isometric strength of the right leg; UL_{left} = unilateral maximal isometric strength of the left leg; BL = bilateral maximal isometric strength of the leg extensor muscles; UL_{grip} = maximal isometric hand-grip strength; DSLD = developmental speech and language disorders; CG = control group.
††$p<0.01$ compared to all other measured groups.
••$p<0.01$ compared to DSLD girls.
*$p<0.05$; **$p<0.01$; ***$p<0.001$ compared to CG boys.

Hand-grip strength

Maximal hand-grip strength of the dominant hand was significantly greater in CG boys compared to boys with mild to moderate DSLD ($p<0.05$), CG girls ($p<0.01$) and girls with mild to moderate DSLD ($p<0.001$) (Table 2). No significant differences ($p>0.05$) in hand-grip strength were observed between CG girls, and girls and boys with mild to moderate DSLD.

Table 3. Descriptive data (mean±SE) of the leg extensor muscles force-generation and relaxation capacity in measured groups.

Paper II	LAT_c (s)	LAT_r (s)	HRT (s)	MVC (N)	RFD_{50} ($N \cdot s^{-1}$)
IEL boys	0.297±0.030	0.390±0.060	0.586±0.140	1310±151*	1488±201*
CG boys	0.313±0.030	0.434±0.070	0.306±0.090	1818±158	2141±201

LAT_c = latency of contraction; LAT_r = latency of relaxation; HRT = half-relaxation time; MVC = maximal voluntary contraction force; RFD_{50} = rate of force development;
IEL = impairment of expressive language; CG = control group.
*$p<0.05$ compared to CG boys.

Vertical jumping performance

Vertical jumping height was lower ($p<0.01$) in girls with mild to moderate DSLD compared to CG girls and boys and in boys with mild to moderate DSLD ($p<0.05$) compared to CG girls and boys (Table 4). The differences in vertical jumping height were insignificant ($p>0.05$) between girls with DSLD and boys with DSLD and between CG girls and CG boys. There were no significant intergroup differences ($p>0.05$) in measured peak vertical ground reaction force.

Table 4. Descriptive data (mean±SE) of vertical jumping performance and eye-hand coordination in measured groups.

Paper I	CMJ_{height} (cm)	CMJ_{force} (N)	$MMDT_{UL}$ (s)	$MMDT_{BL}$ (s)
DSLD boys	13.0±0.4*	1658.9±226.6	117.4±5.4	98.6±5.5
CG boys	15.0±0.4	1861.9±252.1	109.7±5.2	98.1±4.1
DSLD girls	12.0±0.4**	1635.3±252.1	112.1±9.5	85.2±6.3
CG girls	15.0±0.4	1783.5±243.3	110.9±7.2	94.3±2.2

CMJ_{height} = counter-movement jump height; CMJ_{force} = peak vertical ground reaction force during counter-movement jump; $MMDT_{UL}$ = unilaterally performed Minnesota Manual Dexterity Test; $MMDT_{BL}$ = bilaterally performed Minnesota Manual Dexterity Test; DSLD = developmental speech and language disorders; CG = control group.
*$p<0.05$; **$p<0.01$ compared to CG boys and girls.

5.2. Functional motor performance

Minnesota Manual Dexterity Test (MMDT)

The rapidity of performing bilateral as well as unilateral eye-hand coordination tasks did not differ significantly ($p>0.05$) in children with mild to moderate DSLD and controls (Table 4).

Movement Assessment Battery for Children

Table 5 displays the mean values of M-ABC results for IS, percentile, manual dexterity, ball skills and balance of measured groups. Comparison of groups of boys (Paper II) revealed that one boy (3.6%) with mild to moderate IEL achieved scores below 5^{th} percentile suggesting a significant level of motor impairment. Four boys (14.3%) with IEL and one boy (3.8%) in control group scored between 5^{th} and 15^{th} percentile showing moderate levels of motor problems. There were significant differences for the IS and percentile ($p<0.001$), for ball skills and for balance ($p<0.01$) between two groups of boys, where performance of boys with mild to moderate IEL was considerably poorer. There were no statistically significant differences ($p>0.05$) between measured groups in manual dexterity.

Table 5. Descriptive data (mean±SE) of performing the Movement Assessment Battery for Children in measured groups.

Papers	IS (points)	Percentile	Manual dexterity (points)	Ball skills (points)	Balance (points)
Paper II					
IEL boys	6.2±0.9***	41.3±5.3***	1.6±0.3	2.6±0.5**	2.0±0.5**
CG boys	2.1±0.6	72.7±5.1	0.8±0.2	0.7±0.3	0.7±0.3
Paper III					
IEL children	7.2±1.1***	38.2±5.2***	1.9±0.5*	2.7±0.5**	2.5±0.5**
AD children	3.6±0.7††	58.6±5.1††	1.1±0.4	1.6±0.4	0.8±0.4†
CG children	2.2±0.6	73.4±5.9	0.7±0.2	0.9±0.3	0.7±0.3

IS = impairment score; IEL = impairment of expressive language; CG = control group; AD = articulation disorders.
*$p<0.05$; **$p<0.01$; ***$p<0.001$ compared to CG boys/children.
† $p<0.05$; †† $p<0.01$ compared to IEL children.

Comparison of children with mild IEL, mild AD and controls (Paper III) revealed significant differences between IEL children and controls for the impairment score ($p<0.001$), percentile ($p<0.001$), manual dexterity ($p<0.05$), ball skills ($p<0.01$) and balance ($p<0.01$), where performance of children with IEL was considerably poorer. Two children (6.9%) with mild IEL achieved scores suggesting a significant level of motor impairment. Four children (13.8%) with mild IEL and one child (3%) in control group showed moderate (borderline) levels of motor problems. Children with mild IEL performed significantly poorer also compared to children with mild AD for the impairment score ($p<0.01$), percentile ($p<0.01$) and balance ($p<0.05$). There were no statistically significant differences ($p>0.05$) in M-ABC results between children with mild

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AD and controls. Two children (7.4%) with AD showed moderate levels of motor difficulties.

5.3. Haptic perception

Table 6 displays the mean values of haptic object-recognition task. Boys with mild or moderate IEL made considerably more errors (*p<0.001*) in HOR task than boys of control group (Paper II). Also the children with only mild IEL performed significantly poorer (*p<0.01*) in HOR task compared to CG children (Paper III). No significant differences (*p>0.05*) in haptic object-recognition were found between children with mild AD compared to controls or children with mild IEL (Paper III). The percentage of right answers in children with mild IEL was markedly lower (*p<0.01*) and percentage of wrong answers considerably higher (*p<0.01*) compared to CG children. There were no significant differences (*p>0.05*) between measured groups in the percentage of right answers given after 5 s or after correction.

Table 6. Mean (±SE) values of haptic object-recognition task in measured groups.

Papers	HOR (points)	Right answers (%)	Wrong answers (%)	Right answer after 5 s (%)	Corrected answers (%)
Paper II					
IEL boys	4.9±0.6***				
CG boys	2.5±0.4				
Paper III					
IEL children	4.7±0.6**	54.5±5.2**	21.4±3.6**	17.9±3.9	6.2±2.2
AD children	3.2±0.6	63.7±5.4	13.3±3.5	21.5±4.3	1.5±1.0
CG children	2.7±0.4	70.7±3.1	10.0±2.7	15.3±3.4	4.0±1.8

HOR = haptic object-recognition; IEL = impairment of expressive language; CG = control group; AD = articulation disorders.
***p<0.01* compared to CG children; ****p<0.001* compared to CG boys.

5.4. Social interaction abilities

The mean score for SI evaluated by kindergarten teachers was considerably higher in children with IEL (*p<0.01*) compared to controls, indicating poorer SI abilities (Table 7; Paper III). There were no significant differences (*p>0.05*) in SI score of children with mild AD compared to the same parameter of controls and IEL children. The concurrency of ratings given by teachers was 76%.

The kindergarten teachers evaluated that children's spoken language is well comprehensible by adults in 43.8% of cases in IEL group, 72.5% in AD group and 81.6% in control group; and by peers the respective shares were 54.4%, 78.4% and 85.0%. The questionnaire also revealed that children had several playmates in 54.4% of cases in IEL group, 58.8% in AD group and 71.7% in control group. Besides, it emerged that the children did not participate spontaneously in social or sporting games in 3.5% of cases in IEL group, 2.0% in AD group and 1.7% in control group.

Table 7. Characteristics of social interaction abilities in subjects (mean±SE).

Paper III	IEL children	AD children	CG children
SI (points)	6.0±0.3**	5.4±0.3	4.9±0.2

SI = social interaction; IEL = impairment of expressive language; AD = articulation disorders; CG = control group.
**$p<0.01$ compared to CG children.

6. DISCUSSION

6.1. Muscle force-generation capacity

The present study (Paper I and II) was designed to develop a better understanding of the muscle strength and relaxation capacity in children with mild to moderate developmental speech and language disorders.

Collected data demonstrated that maximal isometric strength of the LE muscles during UL and BL contraction was considerably lower in girls with mild to moderate DSLD compared to other measured groups (Paper I). The maximal isometric strength of the LE muscles during UL and BL contraction in boys with mild to moderate DSLD, on the contrary, did not differ significantly from the corresponding parameters of control group children. Also, there were no significant differences between CG girls compared to CG boys in maximal isometric strength of the LE muscles.

Maximal isometric hand-grip strength of the dominant hand was the lowest in girls with mild to moderate DSLD (Paper I), although statistically significant difference emerged only in comparison with CG boys. Boys of the CG demonstrated greatest hand-grip strength compared to all other measured groups. Surprisingly, there were no significant differences between girls and boys with mild to moderate DSLD compared to CG girls in hand-grip strength.

Distribution of the subjects by type of speech and language disorders revealed that boys with mild to moderate IEL had considerably lower maximal isometric force-generation capacity compared to CG boys (Paper II). However, there were no statistically relevant differences between these two groups of boys in latency of contraction, latency of relaxation and half-relaxation time of the LE muscles.

Anthropometric characteristics, mainly body height and body mass, are important factors which influence the recording of muscle function (Beunen et al. 1992, De Ste Croix et al. 1999). In current study, no significant differences in anthropometric characteristics were found between the girls with DSLD, boys with DSLD and CG boys. CG girls tended to be slightly taller compared to other measured groups and weight slightly more compared to both groups of boys. As the isometric strength of girls with mild to moderate DSLD was lowest compared to all other measured groups, these differences cannot be explained only with anthropometric parameters.

Although some authors (Kanehisa et al. 1995, De Ste Croix et al. 1999, Seger and Thorstensson 2000, Pääsuke et al. 2003) have not observed significant gender differences in maximal voluntary force-generation characteristics of skeletal muscles before puberty, our results are in agreement with other preliminary studies (Raudsepp and Pääsuke 1995, Lefevre et al. 1998, Molenaar et al. 2010) indicating that over the pre-pubertal period the boys have moderately greater muscle strength than girls, whereas differences in the maximal voluntary force-generation capacity of skeletal muscles were especially expressed for the hand-grip strength. This finding is in line with the study of Molenaar et al. (2010) where hand-grip strength in 4–6-year-old boys was up to 34% greater than in girls. One possible explanation is that boys are usually physically more active and take more often part in games which demand strength, agility and skills compared to girls.

Several studies (Reeves 1995, Hill 1998, Chow and Henderson 2003, Webster et al. 2006, Visscher et al. 2007, Cheng et al. 2009, Rechetnikov and Maitra 2009) have shown that motor impairment is a common co-morbidity in children with DSLD. Unfortunately, they have not described the muscle strength characteristics in these children but have indicated deficits in the performance of functional motor tests. Our collected data was in accordance with these findings, but also revealed relevant differences in maximal force-generation capacity of skeletal muscles in case of girls with mild to moderate DSLD and of boys with mild to moderate IEL. The lower MVC force and rate of force development of the LE muscles in boys with mild to moderate IEL refer patently to the relevance of distinguishing between different types of speech and language disorders, as a corporated group of boys with DSLD could not show such deficit in force-generation capacity of the LE muscles that characterizes subjects with solely IEL.

Differences in muscle strength cannot be explained solely by differences in body size, muscle mass or gender differences. Several central (neural) and peripheral (muscular) factors can determine the differences in muscle voluntary force-generation capacity. The neural control of muscles in children is closely related to the maturation of the nervous system. It has been suggested that the expression of muscle strength is dependent on the myelination of the motor nerves (Brooks and Fahey 1985, De Ste Croix et al. 1999) and recruitment of motor units (Ramsay et al. 1990, Fricke and Schoenau 2005, Falk et al. 2009), which are major factors for the contraction force of the muscles. Neuromuscular determinants as optimal agonist muscle activation and antagonist muscle coactivation, in other words, adequate muscle coordination, have also been pointed out (Ozmun et al. 1994, Maganaris et al. 2001, Stackhause et al. 2005) to quote muscle strength.

The lower maximal muscle force-generation capacity in girls with mild to moderate DSLD and in boys with IEL seems to be limited by the ability to activate agonist muscles and/or to control antagonistic muscles during maximal voluntary contraction. One possible factor may be less developed central processing mechanisms during voluntary effort. This is in good accordance with Hill (1998) and Shevell et al. (2005), who noted that DSLD may reflect a maturational lag or immaturity rather than a specific disorder or defect. A number of other authors have pointed out that speech and language disorders are associated with fine- and gross-motor problems, but their performance is not characterised as deviant, but rather, is comparable to that of younger peers (Bishop 1992, Visscher et al. 2007). Age, as has been emphasized by several authors (De Ste Croix et al. 1999, Neu et al. 2002, Molenaar et al. 2010), is the major determinant in the development of muscle strength in children. Thus, the lower voluntary force-generation capacity of the skeletal muscles in girls with mild to moderate DSLD and in boys with IEL is possibly related to the differences in neurodevelopmental stage, which causes lower level of motor coordination and/or lower ability to recruit the high threshold fast motor units with fast twitch muscle fibres under maximal voluntary contraction.

It has been described (Miller et al. 2006, Peter and Stoel-Gammon 2008) that children with language impairment are significantly slower than controls in speed-requiring motor tasks, suggesting that the speed of processing in children with DSLD is generally slower. As the reaction time of muscle activation was not prolonged in boys with mild or moderate IEL compared to controls, we can suggest that speed of processing and movement preparation were not affected in subjects of our study. Unfortunately, less attention has been paid to studying muscle relaxation speed in children with DSLD. Some authors (Lin et al. 1994, Morse et al. 2008) have observed that younger childrens' muscles are initially slow to relax. Two main factors have been described as responsible for the rate of muscle relaxation: sarcoplasmic reticulum Ca^{2+} uptake and the rate of cross-bridge kinetics (Westerblad et al. 1997, Hamada et al. 2000). The results of present study indicated that in boys with mild to moderate IEL these intracellular processes do not occur less intensively in comparison with age-matched controls.

Vertical jumps can be used as a model to study explosive force-generation capacity of the lower extremities. The results of present study (Paper I) showed a markedly lower vertical jumping height in children with mild to moderate DSLD compared to control group children, although there were no intergroup differences between recorded peak vertical ground reaction force.

Vertical jumping is a multi-joint movement and requires the intra- and intermuscular coordination, which describes the ability of agonist, antagonist and synergist muscles to cooperate in performing the task. This ability depends on the sufficient maturity of nervous system. The less developed motor coordination in children with DSLD compared with normally developing children has been shown by several investigators (Cermak et al. 1986, Owen and McKinlay 1997). This result is in accordance with the study of Merrimann et al. (1993) showing that peak force in children with DSLD is not lower compared to control group children, differences emerging only in the components of jumping movement. Thus, lower jumping height in children with mild to moderate DSLD seems to be limited by the muscle coordination, precisely by the ability to control antagonistic muscles during explosive force-generation. Relatively equal production of peak vertical ground reaction force in measured groups confirms this theory. Results of this study support the hypothesis that poorer motor control in children with DSLD occurs due to slower neurodevelopment.

6.2. Functional motor performance

The results of *Minnesota Manual Dexterity Test* showed that eye-hand coordination of children with mild to moderate DSLD and of CG children did not differ significantly (Paper I). Several authors have indicated poor visual-motor ability (Carroll et al. 1989, Owen and McKinlay 1997, Newmeyer et al. 2007) and impaired motor hand function (Preis et al. 1995, Bishop 2002, Ozcebe et al. 2009) in children with DSLD. However, results of our research (Paper I) are in line with the study of Zelaznik and Goffman (2010) showing no differences in timing skill in the manual domain and with the study of Reeves (1995), who demonstrated that the fine-motor skills of the 5-year-old children with DSLD did not differ from the normative sample. Significant differences in this parameter emerged only between 3- and 4-year-old children with DSLD compared to CG children. As all children who participated in our study, had mild to moderate DSLD, we can assume that eye-hand coordination is evidently impaired only in case of severe DSLD. One possible reason for age-appropriate eye-hand coordination in children with DSLD is the fact that in this study (Paper I) we did not set apart children with different types of speech and language disorders that could have masked the real outcome. Besides, the training effect could also influence the results. All children with DSLD participating in our study received professional speech therapy, one part of which is the improvement of fine-motor skills by eye-hand coordination tasks. This exercising could minimize the differences between DSLD group outcomes compared to regularly developing children.

The scores of *Movement Assessment Battery for Children* demonstrated that general functional motor performance in children with IEL was considerably lower compared to typically developing children. Boys with mild to moderate IEL obtained markedly poorer scores in ball skills and balance subtests compared to controls (Paper II). Analysis of functional motor performance in children with mild IEL (Paper III) confirmed that they have poorer results in ball skills and balance, as well as in manual dexterity subtests compared to CG children. Furthermore, their test results were also worse compared to children with mild AD in overall M-ABC test and in balance subtest. Interestingly, there were no significant differences in manual dexterity, ball skills or balance in children with mild AD compared to typically developing peers (Paper III).

These results are in accordance with the previous studies (Shevell et al. 2005, Webster et al. 2006, Visscher et al. 2007, Rechetnikov and Maitra 2009) where children with DSLD demonstrated deficits in overall M-ABC results. Although articulation is greatly dependent on motor skills (Bernthal and Bankson 1998) and AD refers to the fine- and oral-motor dysfunction (Ettala-Ylitalo and Laine 1991, Newmeyer et al. 2007), there are no data considering gross-motor performance in children with this problem. Cheng et al. (2009) emphasized that most remarkable differences between children with DSLD and controls do not emerge in the tests of ball skills or balance, but in manual dexterity. Our results are in line with Visscher and colleagues (2007), who demonstrated that balancing on one leg is the most discriminating measure between children with DSLD and normal sample. Results of this study also confirmed the conclusion of Estil et al. (2003) that children with expressive oral language problems perform poorly in the tests of bimanual coordination and static balance. It has to be stressed that these studies observed mostly children with moderate or severe speech and language disorders from special schools. The results of our research revealed functional motor difficulties even in children with mild IEL but not in children with mild AD. Relying on the results of M-ABC, we propose that motor difficulties in children even with mild IEL, diversely from children with AD, engage more extensively the functions of the whole body, while the dysfunction of articulators is limited and does not affect general motor performance.

Interestingly, it has been found that important brain structures involved in speech and language production (Fabbro et al. 1996), sequencing, speed, ball skills and balance control (Timmann et al. 1999, Bulloc 2004, Ullman and Pierpont 2005, Visser and Bloem 2005), are cerebellum and basal ganglia. Drawing the parallel with lower force-generation capacity in children with DSLD that can be explained by slower neurodevelopment, the lower functional motor performance could also be elucidated by the immaturity of these brain structures. The other explanation is that the poorer motor performance may be a consequence of less practice through play and sport activities, because children with DSLD are more socially isolated.

6.3. Haptic perception

In the haptic object-recognition task, children with IEL made considerably more errors than controls (Paper II–III). Further analysis revealed that children of CG gave the highest percentage of right answers and lowest percentage of wrong answers (Paper III). However, differences between children with mild AD and controls were statistically insignificant.

These results confirmed previous notions (Kamhi et al. 1984, Giannopulu et al. 2008) that children with DSLD have lower ability to recognize common objects haptically. However, several researchers (Montgomery 1993, Accardi 1997, Kiesel-Himmel 2008) have emphasized that children with DSLD are not deficient in their proprioceptive abilities but they might have problems with performing adequate exploratory procedures or with complex cognitive capabilities like tactile short term memory and cross-modal transfer. The complex movements during haptic object recognition are mainly under the dependence of the posterior cerebellum for motor coordination (Habas and Cabanis 2008) and basal ganglia for performing skills involving sensorimotor sequences (Penhune et al. 1998, Ullman and Pierpont 2005). Although the deviations in articulation are associated with poorer oral stereognosis (Schliesser and Cary 1973), our study results demonstrated that this does not extend to object recognition by touch. Considering the assumption of immature neurodevelopment in children with mild to moderate IEL, poorer haptic performance refers most likely to their inability to select and/or perform appropriate EPs. As the manual dexterity in children with DSLD and in boys with IEL was not uniquely impaired compared to controls, it is not likely that difficulties in haptic object-recognition is caused by improper processing kinaesthetic inputs or by dysfunction of involved brain structures.

6.4. Social interaction abilities

The idea of the measurement of SI ability in children with mild IEL and AD was to verify the existence of communication difficulties and engagement in play with peers. Results of the composed questionnaire revealed that in children with mild IEL the overall social interaction skills were relevantly poorer compared to children with AD and controls (Paper III). Furthermore, their speech intelligibility was considerably poorer and they tended to play alone often compared to other measured groups. Children with AD, on the other hand, did not demonstrate such deviation in social interaction.

Findings of this study were similar to the findings of Fujiki et al. (1999), where children with DSLD were less preferred playmates and were often subjects of peer rejection compared to typically developing peers. To explain the lower scores in children with DSLD in motor tests, some authors have brought out the environmental factor (Webster et al. 2006, Visscher et al. 2007), suggesting that children with DSLD have lower social acceptance, which entails less participation in play and sport activities (Gertner et al. 1994, Snowling et al. 2006). As a consequence, a lack of practice of motor skills may occur, which may result in low levels of motor skills. Furthermore, for children with both speech and language disorders, it is not inconceivable that having both disorders has a greater impact on social functioning and social behaviour than only language disorders because of the more complicated communication (Webster et al. 2006, Visscher et al. 2007). Findings of this study confirmed that children even with mild IEL are more isolated and do not participate in spontaneous play and sport activities as much as typically developing children.

However, it is more likely that motor difficulties in children with mild IEL are prevalent due to the vicious circle where lower motor skills are causing clumsiness in age-appropriate play and sport activities, that entails isolation from games with peers and in turn lack of practice of motor skills.

This study showed that preschool children with even mild IEL are inferior in motor performance, haptic perception and social interaction compared to children with AD and healthy peers. Dysfunction in sensorimotor performance was expressed especially in lower muscle strength and coordination, poorer ball skills, balance and haptic object-recognition. Our results support the idea that unlike AD, the IEL is not an isolated phenomenon, but rather that other deficits – including motor and haptic perception deficit – accompany the impairment. Identification of concrete developmental problems would improve the chances of determining the most favourable treatment and the implementation of an integrated occupational, physical, and speech therapy approach.

The data available for the study are cross-sectional and thus do not indicate a causal relation between DSLD, motor skills, haptic object-recognition and social interaction ability. Another study limitation was the absence of standardized test batteries for the measurement of HOR and SI. Nevertheless, the findings add to the accumulating evidence that deviant motor performance as well as haptic perception and lower social acceptance may be a significant factor even in children with mild IEL but not in children with AD.

CONCLUSIONS

1. The isometric voluntary force-generation capacity of the leg extensor muscles is lower in girls with mild to moderate DSLD and in boys with IEL compared with age- and gender-matched healthy children. The capacity for rapid voluntary contraction and relaxation of the leg extensor muscles does not differ in boys with mild to moderate IEL compared to controls.
2. Children with mild to moderate DSLD have lower vertical jumping height, whereas peak vertical ground reaction force during take-off phase does not differ from typically developing children.
3. The eye-hand coordination does not differ in children with mild to moderate DSLD compared to age- and gender-matched controls.
4. Overall functional motor performance in children with mild or moderate IEL is poorer compared to healthy children and children with mild AD. Poor motor performance in children with IEL is most pronounced for ball skills and balance. The functional motor performance does not differ in children with mild AD compared to typically developing peers.
5. The haptic object-recognition is poorer in children with mild or moderate IEL compared to age- and gender-matched controls. Haptic object-recognition in children with mild AD is in level with regular children.
6. The social interaction ability is lower in children with mild IEL compared to normative sample. There are no significant differences in social interaction ability between children with mild AD and typically developing children.

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SUMMARY IN ESTONIAN

Sensomotoorsed võimed ja sotsiaalsedoskused arengulise kõnehäirega lastel

Sissejuhatus

Kõnehäire on kõige sagedamini esinev arenguline probleem eelkoolieas, mida esineb kuni 14%-il lastest, seejuures poistel märkimisväärselt enam kui tüdrukutel. Kõne ja keele spetsiifilisi arenguhäireid defineeritakse kui isoleeritud häireid kõne produtseerimisel või kõne mõistmisel juhul, kui lapse areng kõigis teistes valdkondades vastab ealistele normidele. Uuringud on aga näidanud antud definitsiooni ebatäpsust, sest kõnehäirega lastel esineb tavapärasest sagedamini õpiraskusi, sotsiaalseid ja käitumuslikke kõrvalekaldeid ning ka motoorseid probleeme. Kuna kõne produktsioon on peenmotoorseid oskusi nõudev tegevus, siis on kõnehäireid valdavalt seostatud just peenmotoorse, nii käelist kui ka oraalmotoorikat hõlmava kõrvalekaldega. Mitmed uuringud on seda arvamust kinnitanud ning näidanud peenmotoorsete oskuste häirumist kõneprobleemiga lastel. Jämemotoorseid oskusi on vastaval kontingendil uuritud seevastu vähem, kuid saadud tulemused on viidanud mahajäämuse esinemisele ka funktsionaalsetes motoorsetes oskustes. Paraku puuduvad kirjanduses andmed kõnehäirega laste lihaste jõugenereerimis- ja lõõgastusvõime kohta ning puudulik on informatsioon ka sensoorse funktsiooni iseärasuste osas. Psühholoogia valdkonnas läbiviidud uuringud on leidnud, et kõnehäirega lastel esineb oluliselt rohkem raskusi sotsiaalsete suhete loomisel ja hoidmisel oma eakaaslastega.

Sensomotoorsete võimete ja sotsiaalsete oskuste erinevaid aspekte käsitlenud uuringutes on vaatlusalustena kasutatud valdavalt raskete kõnehäiretega lapsi. Suuremal osal lastest on kõnehäired aga kas kerge või mõõduka raskusastmega. Ehkki kõnehäireid on mitut erinevat liiki (nt. artikulatsioonihäire, ekspressiivne, retseptiivne ja ekspressiiv-retseptiivne kõnehäire), puuduvad andmed laste sensomotoorsete funktsioonide ja sotsiaalsete oskuste eripära kohta lähtuvalt kõnehäire liigist.

Uurimistöö eesmärk ja ülesanded

Uurimistöö eesmärgiks oli välja selgitada sensomotoorsete võimete ja sotsiaalsete oskuste iseärasused kerge või mõõduka kõnehäirega eelkooliealistel lastel lähtuvalt kõnehäire liigist ning võrreldes tervete eakaaslastega. Töös püstitati järgmised ülesanded:

1. Hinnata skeletilihaste jõugenereerimis- ja lõõgastusvõimet, paigalt üleshüppe võimet, silm-käsi koordinatsiooni ja funktsionaalseid motoorseid oskusi.
2. Hinnata käe stereognoosiat.
3. Analüüsida sotsiaalseid oskusi.

Vaatlusalused ja metoodika

Uuringus osales kokku 93 kõnehäirega ning 78 tavapärase arenguga lasteaialast vanuses 4–6 eluaastat. Esimeses uuringus moodustati vaatlusalustest kerge või mõõduka kõnehäirega poiste ja tüdrukute grupp (vastavalt n=20 ja n=12) sõltumata kõnehäire tüübist ning tervete poiste ja tüdrukute grupp (vastavalt n=21 ja n=24). Teises uuringus moodustasid esimese grupi kerge või mõõduka ekspressiivse kõnehäirega poisid (n=28) ja teise grupi terved poisid (n=26). Kolmandas uuringus võrreldi omavahel kerge ekspressiivse kõnehäirega laste gruppi (23 poissi ja 6 tüdrukut), kerge artikulatsioonihäirega laste gruppi (20 poissi ja 7 tüdrukut) ja tervete laste gruppi (23 poissi ja 7 tüdrukut). Gruppide moodustamisel võeti aluseks Tartu Ülikooli Lastekliiniku logopeedi poolt läbiviidud kõnearengu testide *Reynell Developmental Language Scales* ja *Boehm Test of Basic Concepts* tulemusi.

Alajäsemete sirutajalihaste jõuparameetrite hindamiseks kasutati spetsiaalset elektromehaanilist dünamomeetrilist seadet, mis võimaldas määrata lihasjõudu isomeetrilise kontraktsiooni tingimustes. Alajäsemete sirutajalihaste tahtelise pingutuse ja lõõgastuse hindamisel tuli vaatlusalusel reageerida valgussignaalile maksimaalselt kiire ja tugeva lihaspingutusega, hoida maksimaalset lihaspinget signaali vältel (2 s) ning signaali väljalülitamisel lihased kiirelt lõõgastada. Arvutati masimaalne tahteline kontraktsioonijõud, lihaspingutuse ja lõõgastuse latentsiajad, jõugradient ja lihaste lõõgastuseks kulunud aeg.

Käe pigistusjõudu määrati isomeetrilise käe dünamomeetriga, mida vaatlusalune püstiasendis sirutatud käega maksimaalselt tugevalt pigistas.

Üleshüppevõimet hinnati tensomeetrilisel printsiibil töötaval dünamograafilisel platvormil sooritatud paigalt üleshüppe kõrguse ja äratõukefaasis arendatud maksimaalse survejõu järgi. Paigalt üleshüppeid sooritati püstiasendist ning hüpete ajal hoidis vaatlusalune käed puusal.

Silm-käsi koordinatsiooni hindamiseks kasutati *Minnesota Manual Dexterity Test*'i. Vaatlusalusel tuli ükshaaval võimalikult kiiresti ümber keerata vastaval testimislaual paiknevad nupud esmalt bilateraalselt ning seejärel unilateraalselt dominantse käega. Mõõdeti sooritusele kulunud aeg.

Funktsionaalse motoorse soorituse taseme määramiseks kasutati testi *Movement Assessment Battery for Children*, mille abil hinnati lapse käelise tegevuse kiirust ja täpsust, palli kasutamise osavust ning staatilist ja dünaamilist tasakaalu.

Stereognoosia hindamiseks kasutati riidest kotti, millesse asetati 5 eset (pliiats, lusikas, hambahari, pesunäpits, võti). Vaatlusalusel paluti asetada käsi kotti, võtta pihku üks esemetest ning kompimise teel ära arvata, mis see on. Määrati õigete vastuste arv, valede vastuste arv, latentsiga antud õigete vastuste arv ning korrigeeritud vastuste arv.

Sotsiaalse suhtlemisoskuse hindamiseks kasutati küsitluslehte lasteaia õpetajatele. Iga vaatlusaluse lasteaiarühma kaks õpetajat täitsid eraldi küsimustiku, kus tuli valida esitatud väidetele enim last iseloomustav vastuse variant. Esitatud väited puudutasid lapse kõne mõistetavust teiste laste ja õpetaja poolt, lapse kaasamist spontaansetesse mängudesse eakaaslaste poolt ning tavapäraste mängukaaslaste olemasolu. Rühma õpetajate poolt täidetud küsitluslehtede tulemused summeeriti ning arvutati aritmeetiline keskmine.

Järeldused

1. Alajäsemete sirutajalihaste isomeetriline jõud on kerge või mõõduka kõnehäirega tüdrukutel ja ekspressiivse kõnehäirega poistel tervete eakaaslastega võrreldes märkimisväärselt väiksem. Alajäsemete sirutajalihaste tahtelise pingutuse ja lõõgastuse kiiruses ekspressiivse kõnehäirega ja tervetel poistel olulisi erinevusi ei esine.
2. Keskmise ja mõõduka kõnehäirega lastel on paigalt üleshüppe kõrgus võrreldes tervete eakaaslastega märkimisväärselt madalam. Samas puuduvad olulised erinevused kõnehäirega ja tervetel lastel hüppe äratõukefaasis arendatud maksimaaljõu osas.
3. Silm-käsi koordinatsioonis kerge ja mõõduka kõnehäirega ning tervetel lastel olulised erinevused puuduvad.
4. Funktsionaalse motoorse soorituse tase on kerge või mõõduka ekspressiivse kõnehäirega lastel oluliselt madalam võrreldes nii artikulatsioonihäirega lastega kui ka tervete eakaaslastega. Kerge ja mõõduka ekspressiivse kõnehäirega lapsed saavutavad nõrgemaid tulemusi eelkõige palli käsitlemise osavuses ja tasakaalu parameetrites. Kerge artikulatsioonihäirega ja tervetel lastel olulisi erinevusi funktsionaalsetes motoorsetes oskustes ei esine.
5. Käe stereognoosia ehk esemete kinnisilmi ja vaid kompimise abil äratundmise võime on nii kerge kui mõõduka ekspressiivse kõnehäirega lastel märkimisväärselt madalam võrreldes artikulatsioonihäirega ja tervete eakaaslastega. Erinevused käe stereognoosias kerge artikulatsioonihäirega ja tervetel lastel puuduvad.
6. Sotsiaalsete oskuste tase on kerge ekspressiivse kõnehäirega lastel märgatavalt madalam kui tervetel eakaaslastel. Sotsiaalsete oskuste tasemes puuduvad olulised erinevused kerge ekspressiivse kõnehäirega ja artikulatsioonihäirega lastel ning artikulatsioonihäirega ja tervetel lastel.

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PUBLICATIONS

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Education

2004–2011	University of Tartu, Faculty of Exercise and Sport Sciences, Doctorate Study
2002–2004	University of Tartu, Faculty of Exercise and Sport Sciences, MSc
1997–2002	University of Tartu, Faculty of Exercise and Sport Sciences, BSc (*cum laude*)
1994	Tartu 7th Secondary School

Specialized Courses

2010 ”Application of conductive pedagogy (Petö) methods into the rehabilitation of disabled children and adults”, Tallinn
”Introduction to the internet-based assessment method structured observation of motor performance (SOMP-IT)”, Haapsalu
”Course of making presentations for lecturers and doctoral students”, Tartu

2009 ”Teaching and studying in higher education”, Tartu
”Aids for children – scientific based evaluation of the need and prescription”, Tallinn

2008 “Advancement of physiotherapeutical evaluation – Assessment of neurological patient II, Tartu
“Advancement of physiotherapeutical evaluation – Assessment of gait II”, Tartu
“Advancement of physiotherapeutical evaluation – Assessment of gait III”, Tartu

2007 “Advancement of physiotherapeutical evaluation – Assessment of orthopaedic patient” – Tartu
“Advancement of physiotherapeutical evaluation – Assessment of neurological patient I”, Tartu

Professional Employment

Since 2008	Private practices “BioDesign”, physical therapist
Since 2005	University of Tartu, Institute of Exercise Biology and Physiotherapy, assistant

2003–2009 Tartu University Hospitals, Children`s Clinic, physical therapist
2001–2003 Children's home "Käopesa", physical therapist

Membership in professional organizations

Estonian Union of Physiotherapists – board member.

Scientific activity

Main research interests:

- Functional gross- and fine-motor performance in children with speech disorders;
- Neuromuscular performance in children with speech disorders;
- Sensorimotor abilities in children with speech disorders;
- Cognitive functioning in children with speech disorders;
- Social interaction abilities in children with speech disorders
- Sex differences in motor performance in preschool children.

Publications:

- Articles in international refereed journals – 3;
- Other scientific articles – 8;
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Erialane enesetäiendus

2010	”Konduktiivõppe (Petö) meetodite rakendamine erivajadustega laste ja täiskasvanute rehabilitatsioonis”, Tallinn
	”Introduction to the internet-based assessment method structured observation of motor performance (SOMP-IT)”, Haapsalu
	”Ettekannete tegemise kursus õppejõududele ja doktorantidele”, Tartu
2009	”Õppimine ja õpetamine kõrgkoolis”, Tartu
	”Laste abivahendid – teaduspõhine vajaduste hindamine ja määramine”, Tallinn
2008	”Füsioterapeutilise hindamise arendamine – neuroloogilise haige hindamine II”, Tartu
	”Füsioterapeutilise hindamise arendamine –kõnnianalüüs II”, Tartu
	”Füsioterapeutilise hindamise arendamine – kõnnianalüüs III”, Tartu
2007	”Füsioterapeutilise hindamise arendamine – ortopeediliste haigustega laste hindamine”, Tartu
	”Füsioterapeutilise hindamise arendamine – neuroloogilise haige hindamine I”, Tartu

Erialane teenistuskäik

Alates 2008	Eraettevõte ”BioDesign”, füsioterapeut
Alates 2005	Tartu Ülikool, Kehakultuuriteaduskond, Spordibiloogia ja füsioteraapia instituut, assistent
2004 – 2009	Tartu Ülikooli Kliinikumi Lastekliinik, füsioterapeut
2001 – 2004	Tartu Väikelastekodu ”Käopesa”, füsioterapeut

Erialaorganisatsioonid

Eesti Füsioterapeutide Liit – nõukogu liige.

Teadustegevus

Peamised uurimisvaldkonnad:

- Funktsionaalne peen- ja jämemotoorne võimekus kõnepuudega lastel;
- Neuromuskulaarne funktsioon kõnepuudega lastel;
- Sensomotoorsed võimed kõnepuudega lastel;
- Kognitiivne võimekus kõnepuudega lastel;
- Sotsiaalse suhtlemise oskus kõnepuudega lastel
- Soolised erinevused motoorsetes võimetes eelkooliealistel lastel.

Publikatsioonid:

- Teaduslikud artiklid rahvusvahelise levikuga ajakirjades – 3;
- Muud teadusliku artiklid – 8;
- Konverentside teesid – 8.

DISSERTATIONES KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

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