Umeå University Medical Dissertations, New Series No 1579

Postural balance, physical activity and capacity among young people with intellectual disability

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Umeå 2013

Responsible publisher under Swedish law: the Dean of the Medical Faculty

ISBN:978-91-7459-677-9
ISSN: 0346-6612
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E-version available at http://umu.diva-portal.org/
Printed by Arkitektkopia, Umeå, Sweden, 2013

To my family and friends

It's better to burn out than it is to rust.
Neil Young

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Abstract

The overall aim of this thesis was to investigate postural balance, physical activity, physical capacity and their associations in young people (16-20 years) with intellectual disability (ID), mild to moderate. The aim was also to study the reliability and concurrent validity of postural balance tests.

To evaluate postural balance, one assessor used five common postural balance tests and one new test. The tests were performed twice for 89 young people with ID (one to twelve days apart). Intraclass correlation coefficients greater than 0.80 were achieved for four of the common balance tests: Extended Timed Up and Go Test (ETUGT), Modified Forward Reach Test (MFRT), One-Leg Stance Test (OLS), and a Force Platform Test (FPT). The smallest real difference ranged from 12% to 40%; less than 20% is considered to be low. For the six balance tests, the concurrent validity varied between none to low.

Falls are more common for young people with ID compared to young people without ID. One reason could be impaired postural balance. The postural balance for young people with ID has not been thoroughly investigated. Therefore, five balance tests and three muscle strength tests were used to compare young people with ID with an age-matched control group without ID (n=255). The young people with ID had significantly lower scores on most of the postural balance tests and muscle strength tests of the trunk and lower limbs. Muscle strength, height, and body mass index had no strong association with postural balance. The results also illustrated that young people with ID did not rely more on vision for their balance ability compared to peers without ID.

It seems that postural balance is impaired for young people with ID when evaluated with common tests. An everyday situation is to react to unexpected balance disturbances to avoid falls by using different postural responses. Since young people with ID seem to fall more often than peers without ID, it is valuable to investigate if those postural responses are different between the groups. Therefore, young people with and without ID (n=99) were exposed to six backward surface translations and several postural muscle responses were evaluated: muscle synergies and strategies, muscle onset latency, time-to-peak amplitude, and adaptation. The responses of the investigated muscles – the gastrocnemius, the biceps femoris, and the erector spinae L4 level – were measured using electromyography. The results showed that there were no differences between the two groups with respect to synergies or strategies, muscle onset latency, and time-to-peak amplitude. An overall pattern was seen, that young people with ID adapted their muscle response slower in all three muscles than peers without ID, but this pattern was not statistically significant.

Studies have shown that people with ID have impaired postural balance, a lower level of physical activity, and lower aerobic capacity compared to people without ID. The association is however not investigated. Therefore, postural balance (postural sway indirectly measured with the subjects standing on a force platform), physical activity (measured with a pedometer), and aerobic capacity (measured with a sub-maximal ergometer cycle test) were used to assess young people with and without ID (n=106). To investigate the subjects' view of their own health, the subjects completed an adapted questionnaire that addressed their perceived health. The analysis showed no significant associations between postural balance, level of physical activity, and aerobic capacity. The subjects in the ID group, both men and women, had significantly lower aerobic capacity compared to subjects without ID. The answers from the health questionnaire did not correspond to the measured outcomes from the physical tests for young people with ID.

In conclusion, ETUGT and MFRT can be used to evaluate change in postural balance over time in young people with mild to moderate ID. The low concurrent validity suggests that the postural balance tests probably challenge various subsystems. Young people with ID have impaired postural balance and perform lower on muscle strength tests than age-matched controls. Postural muscle responses after external perturbations seem to be similar for young people with and without ID, but the ability to adapt muscle responses after repeated perturbations appears to be slower for young people with ID. The studies in the thesis also indicate that young people with ID have reduced level of physical activity and lower aerobic capacity. The lack of association between the different physical functions indicates that they should be evaluated and exercised separately. Young persons with ID might have more difficulty realising the health advantage of being physically active, as they do not seem to make this connection. Because of this, it is important that parents/guardians, school staff, physiotherapists, and others encourage them to participate in physical activity.

Svensk sammanfattning

Det övergripande målet för denna avhandling var att undersöka balansförmåga, fysisk aktivitet, fysisk kapacitet och samband mellan dessa hos unga personer (16-20 år) med lätt till moderat intellektuellt funktionshinder (IF). Målet var också att undersöka reliabilitet och validitet hos posturala balanstester.

För undersökning av balansförmåga krävs tillförlitliga och valida test för målgruppen. Fem vanligt förekommande samt ett nytt test utvärderades av en bedömare vid två tillfällen för 89 unga personer med IF (test-återtest med 1-12 dagars mellanrum). ICC-värden större än 0.80 uppnåddes för fyra av testen; Extended Timed Up and Go Test (ETUGT), Modified Forward Reach Test (MFRT), One-Leg Stance Test (OLS) och Force Platform Test (FPT). Den minsta upptäckbara skillnaden varierade mellan 12% till 40%, där värden under 20 % anses som låga. Den samtida validiteten mellan de sex balanstesten varierade mellan låg till ingen varför flera test av balansförmågan ansås nödvändig.

Fall är mer förekommande hos unga personer med IF jämfört med unga utan IF. En orsak kan vara nedsatt balansförmåga. Balansförmåga (fem olika test) och styrka i ben- och bålmuskler undersöktes hos unga män och kvinnor med IF (n=100). Utfallet jämfördes med en åldersmatchad kontrollgrupp utan IF (n=155). Resultatet visade att unga personer med IF presterade väsentligt sämre på de flesta balanstest och alla styrketest jämfört med kontrollgruppen. Muskelstyrka, kroppslängd och body mass index hade inget starkt samband med balansförmåga. Resultat visade också att unga personer med IF inte hade mer syndominerad postural balans jämfört med kontrollgruppen.

Eftersom unga personer med IF verkar falla oftare än unga utan IF och har nedsatt balansförmåga är det viktigt att undersöka deras posturala reaktioner. Unga personer med och utan IF (n=99) testades med sex stycken bakåtförskjutningar av underlaget de stod på, så att de fick ett framåtsvaj kroppen. Posturala muskelreaktioner undersöktes såsom; muskelsynergier, balansstrategier, tid till aktivering efter störning, tid till maximal aktivering och anpassning av muskelsvar efter upprepade förskjutningar. Muskler som undersöktes med elektromyografi var; gastrocnemius, biceps femoris, erector spinae (ländryggsnivå). Resultatet visade att det inte var några skillnader mellan grupperna beträffande; muskelsynergier, balansstrategier, tid till muskelaktivering och tid till maximal muskelaktivering. Dock kunde ett mönster urskiljas att unga personer med IF anpassade sitt muskelsvar mindre än unga utan IF vid upprepade störningar.

Studier har visat att personer med IF har nedsatt balansförmåga, är mindre fysiskt aktiva och har lägre aerob kapacitet jämfört med personer utan IF vilket kan leda till hälsoproblem. Sambanden mellan dessa fysiska parametrar och hälsa har dock inte undersökts. Postural stabilitet (posturalt svaj mätt med kraftplatta), fysisk aktivitetsnivå (stegräknare), aerob kapacitet (submaximalt cykelergometertest) och upplevd hälsa (anpassat frågeformulär) undersöktes hos unga män och kvinnor (n=106). Analysen visade inga signifikanta samband. Unga personer med IF har lägre aerob kapacitet jämfört med ålders- och könsmatchade individer utan IF. Svaren på frågeformuläret överensstämde dåligt med de uppmätta värdena på de fysiska testerna för unga personer med IF.

Sammanfattningsvis visar resultatet från avhandlingen att ETUGT och MFRT kan användas till att utvärdera förändringar i balansförmågan över tid för unga personer med IF. Vidare har unga personer med IF nedsatt balansförmåga och presterar sämre på styrketester jämfört med jämnåriga utan IF. Posturala muskelreaktioner efter yttre balansstörning verkar likartade för unga personer med och utan IF men anpassningen av muskelsvaret vid upprepade störningar förefaller nedsatt hos unga personer med IF. Undersökningarna i denna avhandling indikerar också att unga personer med IF har nedsatt fysisk aktivitetsnivå och lägre aerob kapacitet än unga personer utan IF. Brist på samband mellan postural stabilitet, fysisk aktivitet och aerob kapacitet tyder på att de ska utvärderas och tränas separat. Unga personer med IF verkar ha svårare att se hälsofördelar med att vara fysiskt aktiv. Med hänsyn till detta är det viktigt att de får anpassat stöd från föräldrar/vårdnadsgivare, personal i skolan, sjukgymnaster och andra personer i deras närhet.

Abbreviations

BoS	Base of Support
BMI	Body Mass Index
BSTEET	Biering-Sørensen Trunk Extensor Endurance Test
CI	Confidence Interval
CMJ	Counter Movement Jump
CNS	Central Nervous System
CoM	Centre of Mass
CoP	Centre of Pressure
DOLS	Dynamic One Leg Stance
EMG	Electromyography
ETUGT	Extended Timed Up and Go Test
FPT	Force Platform Test
FTT	Full Turn Test
IEMG	Integrated Electromyography
ICC	Intraclass Correlation Coefficient
ICD 10	International Classification of Diseases, Version 10
ICF CY	International Classification of Function, Disability and Health, Children and Youth
ID	Intellectual Disability
IQ	Intelligent Quotient
MFRT	Modified Forward Reach Test
OLS	One Leg Stance
PA	Physical Activity
SD	Standard Deviation
SEM	Standard Error of Measurements
Sit Ups	Sit-Ups in 30 seconds
SRD	Smallest Real Difference
VO_2max	Maximum Oxygen Uptake
Without ID	People that have not been diagnosed with intellectual disability
WHO	World Health Organization

Original papers

The thesis is based on the following papers, which are referred to by their roman numerals:

I Blomqvist, S., Wester, A., Sundelin, G., Rehn, B. Test-retest reliability, smallest real difference and concurrent validity of six different balance tests on young people with mild to moderate intellectual disability. Physiotherapy 2012;98: 318-324.

II Blomqvist, S., Olsson, J., Wallin, L,. Wester, A., Rehn, B. Adolescents with intellectual disability have reduced postural balance and muscle performance in trunk and lower limbs compared to peers without intellectual disability. Research in Developmental Disabilities 2013;34: 198-206.

III Blomqvist, S., Wester, A., Rehn, B. Postural muscle responses and adaptation to backward platform perturbations in young people with and without intellectual disability. Manuscript.

IV Blomqvist, S., Persson, E,. Sundkvist, H,. Wester, A., Sundelin, G, Rehn, B. Postural stability, physical activity, aerobic capacity, health and their associations – a comparison between young people with and without intellectual disability. Manuscript.

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Preface

In 2005, the Swedish Development Centre for Handicap Sports (Bollnäs, Sweden) started a nutrition, physical activity and health project for people with ID living in group housing. The goal for the project was to invent how different group housings work with improving the health for residents and to develop an education how the staff and the residents should work to improve a healthier life style. Several group housings in Sweden were visited and people (staff and residents) were interviewed. Many interviews revealed that a substantial proportion of residents appeared to have postural balance problems, for example, when going outside in the dark or shopping in the winter. Moreover, the residents often noted they were afraid to fall. They also appeared to have problems getting to work because of impaired postural balance. The staff noted that impaired postural balance could lead to less physical activity and a sedentary life. In addition, physical education teachers, who were also interviewed during this project, told us that many people with ID exhibit postural balance problems, especially when participating in ball sports. These interviews with staff, teachers, and residents suggested that these residents relied on their vision for postural balance more than their peers. Therefore, we assume, people with ID will have problems with postural balance when they cannot trust their vision to keep their postural balance or when they have to focus on something other than maintaining their balance, such as a playing with a ball. After the project ended in 2008, an extensive literature search and a pilot study, funded by The Royal Couples Wedding Fund, revealed that there were few scientific publications about postural balance for people with ID. The pilot study showed that the balance appeared impaired for young people with ID. After that, it was discussed whether an impaired postural balance could also lead to negative consequences for physical activity and physical capacity or the opposite relation (Figure 1). These findings were the origin for this thesis.

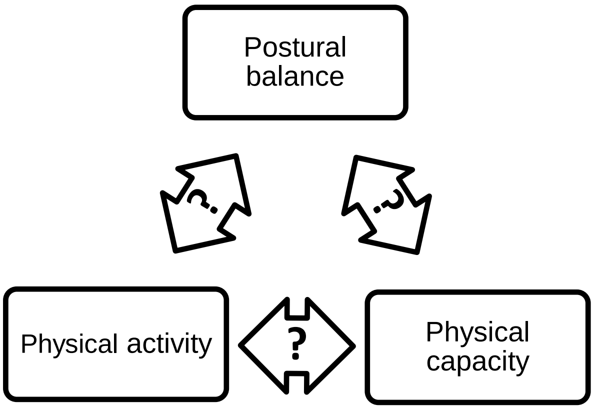

Figure 1. Proposed association between postural balance, physical capacity, and physical activity for young people with ID when this study began.

Introduction

Over the past three decades, people with ID have improved their health conditions as is evident by the fact that people with mild ID now have the same life expectancy as people without ID. Despite these improvements, people with ID are still less healthy compared to the general population. A recent Swedish study showed that 57% of people with ID have musculoskeletal disorders, 49% are overweighed, 18% have high blood pressure, and 4% have coronary heart disease (Umb-Carlsson, 2008). These findings are in line with international studies that have also shown that people with ID have higher rates of musculoskeletal disorders, obesity, coronary heart disease, and diabetes mellitus than the general population (Temple et al., 2013; Emerson & Baines, 2010; Krahn et al., 2006; van Schrojenstien Lantman-de Valk et al. 1997). Key risk factors that have been documented are physical inactivity and nutrition (Beange, 2002). In a Dutch study by Straetmans et al. (2007), it was reported that people with ID visit healthcare facilities more frequently than the general population (1.7 times more). Physical activity has been reported to have positive effects on health for persons with obesity, cardiovascular diseases, diabetes Type II, cancer, and musculoskeletal disorders (Hallal et al., 2006). A study that investigated regular physical activity in Sweden found that people with ID are less active compared to the general population (Umb-Carlsson, 2008). Impaired postural balance and fear of falling can contribute to inactivity and deconditioning (Hindmarsh & Estes, 1989). Therefore, it is considered important to get additional information regarding postural balance ability and also investigate the association between postural balance and level of physical activity among people with ID. A reduced postural balance could lead to reduced regular physical activity and reversed. This should also affect physical capacities. Most research about postural balance has been done on adults and elderly people and few studies have focused on young people with ID (Enkelaar et al., 2011). Because the consequences of physical inactivity in young people (before adulthood, 16-20 years) tend to manifest later in life (Malina, 2001) and an active lifestyle positively correlates with predictors of good general health status in adulthood (Twisk et al., 2002), research on the young age group appears necessary.

Intellectual disability

There are no official statistics of how many people in Sweden have ID, but many developed countries report a prevalence rate of 1% of the population (Beange, 2002). This would mean that about 90 000 people in Sweden and over 5 million people in Europe have ID.

Intellectual disability is defined by ICD 10 (World Health Organisation's International Classification of Diseases, Version 10, 1996) as "a condition of arrested or incomplete development of the mind, which is especially characterized by impairment of skills manifested during the developmental period". To be classified with intellectual disability the person must a) have an intelligent quotient (IQ) of 70 or below, b) limitation is adaptive behaviour as expressed in conceptual, social, and practical adaptive skills in areas as communication, self-care, education, work, leisure time and health, c) and the disability must have developed before the age of 18. Intellectual disability could be divided in to four levels: mild (IQ 50-70), moderate (IQ 35-49), severe (IQ 20-34) and profound (IQ<20) (WHO, 1996).

In many cases, there is no specific cause of ID as some individuals with ID are simply at the lower end of the normal distribution of IQ, falling on or below an IQ of 70. The majority of people with mild ID are found in this group. In other cases, known causes of ID include genetic, acquired, and environmental/sociocultural factors. The genetic factors can be chromosomal or hereditary disorders. Acquired factors can be prenatal or postnatal traumas. Environmental/sociocultural factors can be poverty and inadequate health care during birth, instability in families, and low education (Katz & Lazcano-Ponce, 2008).

The diagnose ID done by ICD 10 have focus on limitations in adaptive behaviours and not on the physical functions of the person. To describe the physical function of a person with ID, the ICF CY (World Health Organisation's International Classification of Functioning, Disability and Health, Children and Youth, 2007) can be used. In this thesis, the group is defined to have an ID by the ICD 10 and then the focus is on various physical functions as defined by the ICF CY as; b755 - Involuntary movement reaction functions (postural balance), b4551 - Aerobic capacity and b730 - Muscle power functions (muscle strength).

Limitations in adaptive behaviour often requires that people with ID attend special schools and receive help with social interactions such as understanding social conventions, communication with the government, and management of finances. Some people with ID live in group homes and some can live by themselves with support. The support could consist of help with planning, shopping, and cooking and help with hygiene. People with ID could also have problems understanding time, which could lead to difficulties when using public transportation and getting to work or other appointments. Many people with ID can manage regular work if they have support at work with planning and problem solving; people who need a lot of help at work usually work in a sheltered workshop (Daily et al., 2000).

People with ID may have significant problems with daily living because they have limited learning, abstract thinking, and problem solving abilities. These limitations often result in a lack of knowledge on how to live a healthy lifestyle, which could result in health problems (Walsh et al., 2003; Krahn et al., 2006). These health problems are, in part, determined by lifestyle factors such as physical activity and nutrition.

Postural balance

By the time a child turns seven years old, he or she exhibits adult-like postural balance. Around 16 years of age, postural balance is fully developed and as people age their ability to control their postural balance slowly diminishes (Shumway-Cook & Woollacott, 2012).

Understanding postural balance requires understanding postural control. Postural control requires integrating musculoskeletal and neural systems to control the body's position in space, taking into account the task being performed and the environment in which it is performed. According to Shumway-Cook and Woollacott (2012), postural control could be divided into postural orientation (the ability to maintain the different body segments in relation to the environment and task) and postural stability (the ability to control the projection of centre of mass (CoM) within the base of support (BoS)). The CoM is the centre of the total body mass and BoS is defined as the area of the body that is in contact with the supporting surface. When standing upright, the CoM is normally located just in front of the second sacral vertebrae and the BoS is the circumference inscribed around the feet. This definition is valid for static postural balance. Dynamic postural balance is the ability to maintain balance during translation from dynamics to static state and the base of support is also transformed all along, which is considered more challenging for the postural balance system (Ross & Guskiewicz, 2004). Neither postural stability nor balance is used as MESH-terms, so "postural balance" will be used in this thesis, which comprises both static and dynamic postural balance evaluated by clinical and laboratory testing. Postural orientation is not investigated in this thesis.

To develop and maintain postural balance, many systems must interact. Continuous information from the sensory systems (visual, vestibular, and somatosensory structures) regarding the body's position and movement in space and the body's segments in relation to each other is sent to the central nervous system (CNS). This sensory information is integrated and processed at different CNS levels. The CNS sends motor commands to the postural muscles for corrections to maintain the projection of CoM within the BoS. The CNS constantly evaluates the postural balance response with feedback information from sensory systems and continuously adapts the response (Shumway-Cook & Woollacott, 2012). If the postural balance system cannot adapt effectively to different disturbances of the postural balance, this could lead to undeveloped balance ability (Horak et al., 1989).

A deficit or a disturbance in any of the systems used to maintain postural balance could lead to impaired postural balance. These deficits include reduced alignment, reduced muscle strength, reduced flexibility in the joints (Wiacek et al., 2009; Yokoya et al., 2008; Vandervoort et al., 1992; Balzini et al., 2003; Katzman et al., 2007), insufficient sensory information from the visual, somatosensory, or vestibular systems due to aging, trauma, and disease (Nashner & Peters, 1990; Shumway-Cook & Woollacott, 2012; Liu-Ambrose et al., 2006), delayed motor responses that could depend on slow sensory or motor conductions (Inglis et al., 1994), slow spinal conduction (Pratt et al., 1992), or slow central processing (Shumway-Cook & Woollacott, 1985; Woollacott et al., 1986; Stelmach et al., 1989).

Assessment of postural balance

To investigate if an individual or a group has an impaired postural balance, different balance tests should be used to examine the contribution from the different systems (Horak et al., 2009). These balance tests guide the therapist to identify which underlying system that is responsible for an impaired postural balance and also help the therapist with what kind of treatment that is needed for improvements. The tests must be valid and reliable for specific groups, and they should be sensitive enough to detect small changes.

Reliability

Reliability, the consistency of measurements over time, can be relative or absolute (Atkinson and Nevill, 1998. Lexell & Downham, 2005). Relative reliability involves whether subjects maintain their positions in a sample of repeated measurements and absolute reliability involves variability in score of repeated measurements (Shrout & Fleiss, 1979; Bland & Altman, 1990). The Intraclass correlation (ICC) is a popular and preferred retest correlation coefficient (Shrout & Fleiss, 1979) as it has several advantages: it can be used on small samples; it can use data collected on more than two occasions; and different types of ICCs can be used depending on how the raters and subjects were recruited (Lexell & Downham, 2005). For a clinician, the ICC value is difficult to relate to because the value is not on the actual scale of measurement. Therefore, the clinician cannot be sure if a high ICC value for a test actually means low variability at the individual level. Therefore, a more suitable way to estimate reliability is absolute reliability (Bland & Altman, 1990). Different types of absolute reliability can be calculated as the standard error of measurement (SEM) (Atkinson & Nevill, 1998) and the smallest real difference (SRD) (Beckerman et al., 2001). These types of reliability are expressed either in the actual units or as percentages. By expressing reliability as a percentage, it is easier to compare tests that use different units (Lexell & Downham, 2005). Reliability can also be determined for ordinal data and the equivalent to the correlation coefficients is the Kappa coefficients (Sim & Wright, 2005).

Reliability can also be divided in to inter-rater reliability (the subject is tested by two or more different raters) or intra-rater reliablility (the same rater test the subject more than once).

Validity

Validity of a test is the extent a test measures what it intends to measure. Validity places a stress on the purpose of a test and the ability to make conclusions from test scores. Validity suggests that a test has some quantity to determine if scores on a test are related to level of performance in the real world. According to Portney and Watkins (2009), there are four types of validity measurements: face validity (indicates that a test tests what it claims to test); content validity (indicates that the items the makes up the test collets the variables being tested); criterion-related validity (indicates that the outcomes of the test can be used as an alternative for an established test); and concurrent validity (establishes validity between two or more tests when measured on the same subject) (Portney & Watkins, 2009).

Postural balance tests

Clinicians use several tests to evaluate postural balance from various perspectives. The Extended Time Up and Go Test puts demands on the postural balance system by requiring tests subjects to move from sitting to standing and standing to sitting positions and to walk a specific distance, turn around, and return to the starting position. The Modified Forward Reach Test investigates the ability of subjects to shift their centre of mass over their base of support. The One-leg Stance Test measures the ability of subjects to stand on one leg for as long as possible.

One way to examine static postural balance, which is more common for research, is to assess body sway when a person is trying to stand still (postural stability). The postural sway can be measured using a force platform, which provides an indirect estimation of body sway by recording the resulting ground-reaction forces. The CoM projects a force on the platform called the centre of gravity (CoG). The CoG results in a ground reaction force from which the location of the centre of pressure (CoP) can be calculated. The movements of CoP and CoM are closely related, but CoP movements will always be somewhat greater than CoM movements (Palmieri et al., 2002). There are different opinions about the role of the postural sway. One opinion is that the postural sway has no practical role and just represents noise that is a spinoff from the neural control system (Kiemel et al., 2002). Another opinion is that sway is a consequence of a determined process in the CNS searching for postural balance control (Riccio, 1993; Riley et al., 1997). However, increased postural sway has been associated with increased risk of falling (Lafond et al., 2004) young people have been reported to have less sway than older people (Weirich et al., 2010) and an increased postural sway was recorded when subjects' sensory information was less (Woollacott et al., 1986). Postural sway has been considered an excellent measure of the overall health of the postural balance system, but not a good measure of underlying deficits as many disorders increase postural sway (Mancini & Horak, 2010). Measuring postural sway on a force platform has some advantages over clinical tests because a force platform allows for objective scoring, sensitivity to small changes, and less variability in test performance as the instructions for the test are short and easy to understand (Visser et al., 2008) By measuring body sway under different conditions (e.g., eyes open, eyes closed, or standing on a different support) a person's ability to adapt to different sensory information can be investigated (Shumway-Cook & Woollacott, 2012).

Postural responses after perturbations are also used in the laboratory and important to investigate as those reactions provide another view of how postural balance is controlled after sudden unexpected motions of the base of support such as when someone slips or trips. Those reactions are reflex-like, reactions that are not continuous as when a person is standing still (postural sway). Postural responses can be investigated as muscle synergies, balance strategies, response latencies, and adaptations by measuring the postural muscle activity with electromyography (EMG) (Horak et al., 1997). Postural reactions can also be investigated using kinematics (e.g., following the movements of the body) and kinetics (e.g., forces of the body).

Postural balance for people with intellectual disability

Because people with ID may have problems understanding instructions and comprehending information, all postural balance tests that use instructions or information need to be tested for reliability and validity. Most of the postural balance tests for people with ID have not been tested for reliability or validity so more research is needed (Hilgenkamp et al., 2010). In addition, most studies that focus on postural balance in persons with ID have a small sample size, a limitation that could make generalizing results problematic (Hale et al., 2009; Hale et al., 2007; Okuzumi et al., 1997; Suomi & Koceja, 1994; Sparrow et al., 1998; Carmeli et al., 2005).

Most studies about postural balance and ID are done on people with Down's syndrome (DS). DS is just one of many causes of intellectual disability. In this thesis, none of the subjects was diagnosed with DS. Mild to moderate ID was chosen because the majority of people with ID are diagnosed with mild to moderate ID and people with this level of disability likely could understand the instructions.

Only one study about young people with ID and postural balance has been found. This study, which used the Stork Stance Test, found that young people with ID could stand on one foot for shorter time than the control group. The difference also increased with age (Lahtinen et al., 2007). Several studies using a force platform have shown that adults with ID have an increased postural sway compared to control groups (Dellavia et al., 2009; Suomi & Koceja, 1994; van Emmerik et al., 1993; Ko et al., 1992) and have lower scores on the Berg's Balance Scale (Hale et al., 2007). Using the Timed Up and Go Test to investigate balance and gait, two studies have demonstrated that adults with ID performed slower compared to controls (Hale et al., 2007; Bruckner & Herge, 2003). Another study showed that ID people prepared themselves earlier to gain more time to plan and execute the passage move as a response to a hindrance (Sparrow et al., 1998). The ability to shift the CoM was also reduced for adults with ID when tested with the Forward Reach Test (Hale et al., 2007; Cameli et al., 2005). Delays in the central processing of the postural reactions have been seen in young children with DS and in a small sample of adults with ID (Hale et al., 2007; Shumway-Cook & Wollacott, 1985).

Even if the association with postural balance has not been evaluated, falls are reported to be more common for young people with ID compared to peers (Sherrard et al., 2001), and for older adults with ID it seems that falls can occur at a younger age compared to older adults without ID (Cox et al., 2010). About 45 -50% of the treated injuries among people with ID are caused by falls (Hsieh et al., 2001; Bray et al., 2002) and fractures are significantly higher than for an age-matched population (Tannenbaum et al., 1989; Lohiya et al., 1999). Although some research has been made investigating postural balance ability, little is known about young people with ID.

An important age group for studying physical characteristics such as postural balance is young people between 16 and 20 years old. By this age, the body and the sensory systems have matured and the postural balance system should be fully developed. If there are deficient, one needs to manage the deterioration of the balance capacity that appears with aging. From clinical experience, it has been observed that postural balance impairments could be existent already at a young age and some research also supports that recognition (Golubovic et al., 2012). Therefore, more research on postural balance in young people with ID is necessary.

Physical activity

Physical Activity (PA) in adolescents can contribute to the development of healthy adult lifestyle (Hallal et al., 2006) and PA have a positive effects on risks for obesity, cardiovascular diseases, diabetes type II, cancer, and musculoskeletal disorders for adults (Swedish National Institute of Public Health, 2009). In addition, PA have an effect on aerobic capacity, muscle strength, postural balance and also positive effects on cognitive functions (Ferreira et al., 2012; Hillman et al., 2008). The definition for PA is all bodily movements that result in an increased energy expenditure (Caspersen et al., 1985).

In 2010, the WHO recommended the levels of PA needed to prevent non-communicable diseases. In this report, the WHO recommended that children and adolescents (5-17 years) should do at least 60 minutes of aerobic activity with moderate intensity (equivalent of brisk walking) every day and that adults (18-64 years) should do at least 150 minutes of moderate intensity throughout the week (WHO, 2010).

It is difficult to measure PA over time, although there are several methods and each method has advantages and disadvantages. Questionnaires, the most common method, are cheap and easy to administer to many people, but their validity has been questioned because it is difficult to calculate the energy expenditure and people have difficulties remembering and estimating their physical activities (Sallis & Saelens, 2000). Moreover, people with ID have difficulty using questionnaires. PA can also be measured using doubly-labelled water, pulse frequency, accelerometers, and through direct observations, but all of these methods are quite expensive and time consuming. Pedometers (a special type of accelerometer) are simple to use, affordable, and objective, but pedometers cannot determine intensity of PA (Tudor-Locke & Myers, 2001).

Recommendations of how many steps per day an adult should take to be considered physically active is between 10 000 to 12 500 for adults (Tudor-Locke et al., 2008). For adolescents, no such recommendation exists; however, according to a review commissioned by the Public Health Agency of Canada, about 10 000 to 10 700 steps per day is associated with 60 minutes of moderate to vigorous PA (Tudor-Locke et al., 2011), an intensity that corresponds to the WHO's guidelines. No studies have used pedometers to explore PA for young people with ID. However, for adults with ID, aged between 19-65 years, 21% achieved 10 000 steps per day or more (Stanish & Draheim, 2005) and for old adults with ID (50-90 years), 16% reached 10 000 steps per day (Hilgenkamp et al., 2012).

Physical activity among people with ID

Few studies have investigated PA among young people with ID. One study that used a questionnaire for parents to estimate physical activity for their children (4-21 years) found that 56% of young people (11-21 years) are considered active by the old WHO recommendations (30 minutes per day) (Levinson & Reid, 1991). Kozub (2003) using an accelerometer to measure the physical activity of seven young people (13-25 years), found that these people did not meet the old WHO recommendations for PA (Kozub, 2003). Phillips and Holland found that males with ID (16-34 years) took 6558 steps per day and females (16-34 years) took 5648 steps per day, activity that is below the WHO's recommendations (Phillips &

Holland, 2011). A recent study from Taiwan found that 8% of adolescents with ID (16-18 years) met the national PA recommendation of exercising for 30 minutes at least three times per week (Lin et al., 2010). Studies about PA for adolescents without ID have shown that between 50 and 75% met the physical active recommendations (Biddle et al., 2004; Engstrom, 2004; Rasmussen & Eriksson, 2004). More research is necessary to draw conclusions about PA for young people with ID, especially as there is evidence that a high level of PA in adolescents predicts a high level of PA in adulthood (Telama et al., 2005).

Physical capacity

A person's physical capacity is affected by the intensity, duration, and specificity of PA, and there are often significant relationships between daily PA and aerobic capacity (Haskell et al., 2007). Muscular strength and aerobic capacity are considered to be the two most important components of physical capacity for individual health (Ortega et al., 2008b; Fogelholm, 2010).

Aerobic capacity is the ability of the circulatory and respiratory systems to supply oxygen to skeletal muscles during sustained physical activity (Kyrolainen et al., 2010). Different terms are used in the literature; cardiovascular fitness, cardio-respiratory fitness, and VO_2 max. In this thesis, the term aerobic capacity is used to mean estimated maximal oxygen uptake while performing a sub-maximal test. In young people, there are small gender differences in aerobic capacity, but these gender differences increase with age and the capacity among women is about 65-75% of capacity among men in late adolescence. At around 18-20 years of age, the aerobic capacity is at its peak and then gradually declines with age (Rogol et al., 2000; Wilmore & Costill, 1999; Astrand, 1997).

Muscular strength is the ability to generate maximal force with a muscle or a group of muscles, whereas muscular endurance is the ability to perform repeated high resistance contractions (Pate, 1995). Both muscular strength and endurance are factors related to health (Garber et al., 2011). Muscular strength and endurance have been shown to be associated with metabolic health risk factors (Steene-Johannessen et al., 2009); for older adults, there is an association between muscle function and general health (Iannuzzi-Sucich et al., 2002). In this thesis, various aspects of muscle strength are investigated and the term muscle strength is used.

Physical capacity among people with ID

Earlier research about young people with ID and their aerobic capacity seem to be inconsistent. One study that used a maximal oxygen uptake test on a treadmill could not find any difference in capacity between young people (16-21 years) with and without ID (Baynard et al., 2008).

On the other hand, three studies that estimated aerobic capacity (Shuttle run test and Åstrand-Rhyming cycle test) found that adolescents with ID have lower aerobic capacity compared to peers (Salaun et al., 2012; Wallén et al., 2009; Pitetti et al., 2001). The differences in results could be because the use of different test methods and that the groups were also slightly different in age. Therefore, further research is needed.

Few studies have examined young people with ID and muscular strength and endurance, but Pitetti and Yamer found reduced strength in knee extension/flexion and that the combination of leg and back strength was lower for adolescents with ID (15-18 years) compared to an age-matched control group without ID (Pitetti & Yamer, 2002). Similarly, Horvat et al. (1997) found that strength in knee extension/flexion for young adults with ID had 35-40% lower levels compared to non-disabled young adults. When elite athletes (mean 22 years) with ID were compared with physical education students, a reduction in strength for the elite athletes was found that varied between 4 – 27% (Van de Vliet et al., 2006). A Finnish study found significantly lower abdominal strength and endurance in early adolescents (13-17 years) with ID compared to the control groups (Lahtinen et al., 2007). The knowledge about muscular strength and endurance for young people with ID is inadequate and considering that muscular fitness is an important health factor and seems to have some association with postural balance, more research is needed.

For adults, especially older adults with normal development, there seems to be a significant association between muscle strength and postural balance (Carter et al., 2002; Holviala et al., 2006), and reduced leg muscle strength has been recognised as a risk factor for falls (Whipple et al., 1987). The relationship between postural balance and strength for adolescents has also been investigated, but no associations could be found (Granacher & Gollhofer, 2011; McCurdy & Langford, 2006). However, it appears there are some associations between increased postural sway, deficits in strength, and incidence of sport injuries in adolescents (Emery, 2005; Wang et al., 2006). From this view, it seems that young people with ID who have reduced muscular strength can also have impaired postural balance.

Ethical considerations

It is an ethical dilemma to do research on people who have reduced ability to take in information, process it, and draw conclusions. When carrying out research with people with ID, it is crucial to make sure that they fully understand what they sign up for. In spite of the fact that it is difficult to ascertain their understanding of their participation, it is important for them to take part in research in order to gain knowledge about the group regarding health-related matters such as postural balance, physical activity, and physical capacity. The planning and preparation for this thesis has tried to consider optimal experimental designs, amount of research, and the test person’s well-being and integrity.

Information about the studies and the test person’s rights were presented both verbally and in easily to understand written texts. When persons with ID were informed about the study, we strove to provide an environment where the test person felt safe and tried to have a person who knows the test person present. The test person was notified that they could withdraw at any time without any explanation and that their anonymity was guaranteed when the test results were presented. All test results in this thesis are presented on a group level where no single test person is mentioned by name and no characteristics are mentioned that could reveal the identity of the test person.

Any person over sixteen has the right to decide if she or he wants to take part in research (Vetenskapsrådet, 2012); however, to avoid misunderstandings and to help the person with ID decide if she or he wanted to sign up for a study, we informed the parents/guardians and school staff about the study so they could help the test person understand what the study was about and support the person’s decision. In this thesis, all people under 18 years of age had to have their parents/guardians approve their participation.

Before each test, the test persons were informed how the test was done and was shown how the test should be conducted to feel safe. Concerns about the test person’s well-being during the testing session were addressed frequently and the sessions were paused if the test person wanted or needed a break.

The studies that are included in this thesis have been approved by the regional Ethics Review Board in Umea, Sweden (No. 09-076M and No. 2012-13-32M).

Rational for the thesis

Falls are more common among people with ID compared to the population in general and people with ID do not reach the WHO’s recommended level of activity, two situations that could be the result of impaired postural balance. Tests that investigate postural balance must be reliable and sensitive enough to detect small changes over time, but for the moment there are no such tests for young people with ID and research about postural balance in people with ID and especially in young people is scarce (Figure 2). Clinical observations suggest that people with ID seem to rely more on their vision to control their postural balance than peers without ID. There are few studies on this topic and these studies’ results are not in agreement.

People with ID seem to have impaired postural balance, lower level of physical activity, and lower physical capacity, but the associations between these factors for young people are unknown. For older people, the association has been investigated; Voelcker-Rehage et al. (2010) found a strong association between aerobic capacity, balance, movement speed, and cognitive functioning. This finding suggests that these associations could also be present for young people with low cognitive function.

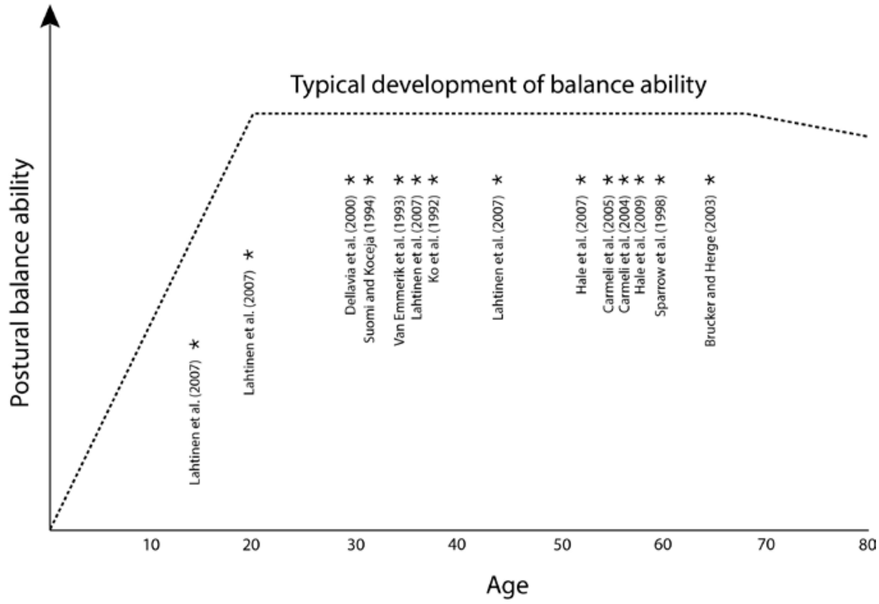

Figure 2. Scientific studies about postural balance among people with ID. The black dotted line in the figure represents a suggested typical development of postural balance for people in general and the different marks represent research that compared postural balance with people having an ID. The figure reveals that postural balance seems impaired for people with ID throughout their lifespan, but more research is needed, especially for young (younger than 20 years) where only one study has investigated postural balance.

Aims of the thesis

The overall aim for thesis is to evaluate postural balance, physical activity, and physical capacity for young people with intellectual disability. Four specific aims are addressed:

To examine the reliability of five common and one new postural balance tests and also to examine the concurrent validity among these balance tests (Paper I);

To investigate postural balance and muscle strength among young men and women with ID and to compare them with peers without ID and to investigate whether muscle strength, height, BMI and vision have any associations with postural balance (Paper II);

To investigate postural muscle responses after external perturbations in young people with ID and to compare them with peers without ID (Paper III); and

To investigate associations between postural stability, physical activity, aerobic capacity and health for young men and women with and without ID (Paper IV).

Methods

This thesis includes four papers: a paper that examines reliability and validity of postural balance tests; a paper that compares postural balance and muscle strength; a paper that examines postural muscle responses; and a paper that examines associations between postural stability, physical activity, physical capacity and health. All four studies had a cross-sectional design (Table 1).

Recruitment

All subjects in the four studies were recruited from two upper secondary schools in the middle of Sweden – one school for students with ID and one school for students without ID. The principals of the two schools were contacted in order to obtain approval to visit the school and to inform the students about the study. Oral and written information was given to all students in the two schools. If the students were interested in participating in the study, they signed a form. For all students with ID who were under 18 years old, written information was sent home to their parents/guardians with information about the study and with a request to return a signed approval form allowing their son/daughter to participate. Only students who returned the signed approval form were allowed to take part. All subjects in the four papers in this thesis were sampled from this pool (142 young people with ID and 269 without ID). Several of the subjects participated in more than one study (Figure 3).

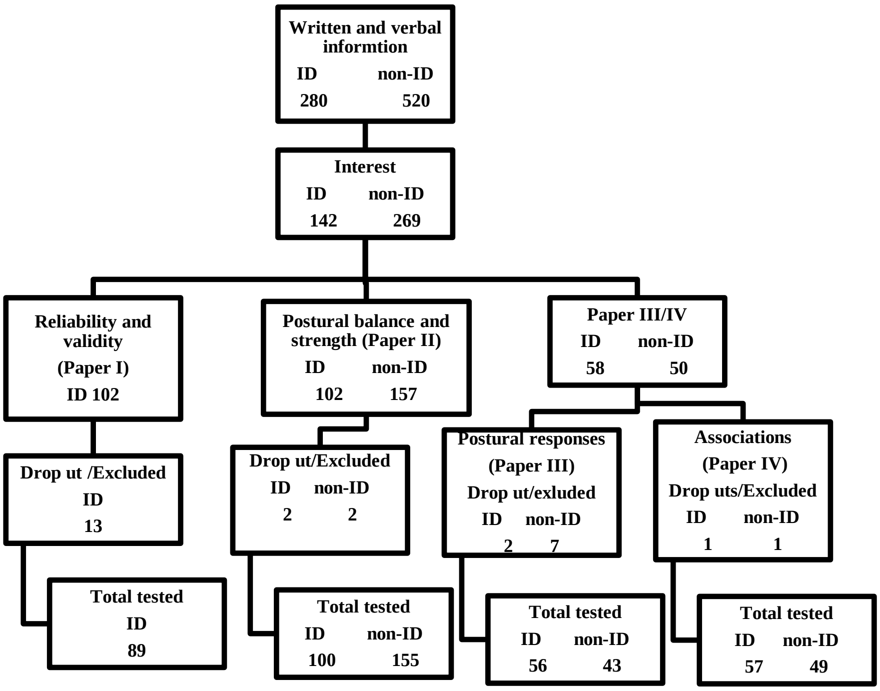

Figure 3. Flow chart of the sample selection procedure for the subjects in this thesis. (ID, Intellectual disability). Note that several subjects participated in more than one study.

Inclusion and exclusion criteria

To participate in the study, all the young people had to be between 16 to 20 years old. The young people with ID, the inclusion criteria were also that they had to be defined as having mild to moderate ID (IQ 70-35) by an intellectual function test (IQ-test), limitation in adaptive behaviour in two or more skills as conceptual, social and practical function. The exclusion criteria for both groups were recent injury in lower extremities, illness, impaired vision (visual acuity value >0.10), history of or on-going vestibular neuritis, use of walking aids, and a diagnosis of cerebral palsy (CP). The people with ID were also screened (clinical investigation) for sensory deficits in lower extremities (loss of sensibility, affected stretch reflexes, or reduced strength). An interview with each prospective participant was done regarding his or her history of injury, illness, vestibular neuritis, CP, and use of walking aids. Vision was checked using an eye chart and sensory deficit in the lower extremities was screened.

Measurements

Reliability and validity

Postural balance

The Extended Timed Up and Go Test (ETUGT) was used to measure dynamic balance and gait speed. The test was extended as described by Wall et al. (2000). Instead of walking three meters, as in the original test, the subject was asked to rise from a chair and walk nine meters before returning to the chair and sitting down. The extended test was chosen because it has been used for subjects with ID earlier (Carmeli et al., 2002). It is simple to do, has good reliability, and can predict risk of falls in elderly (Yelnik & Bonan, 2008; Shumway-Cook et al., 2000; Whitney et al., 2005). The time was measured (seconds) and the best attempt of three was recorded.

The Modified Forward Reach Test (MFRT) was used to measure the ability to reach forward (shifting the CoM) as far as possible without losing balance and take a step. A modification of the original test (Duncan et al., 1990) was done because people with ID had difficulty understanding the original test. Instead of estimating how far a subject can reach measured with a ruler on the wall, the subject had to push a metal plate that was gliding on a beam between to tripods. How far the metal plate was pushed was measured (centimetres) three times and the best trial was collected. The original test can predict fall risk (Behrman et al., 2002) (Figure 4).

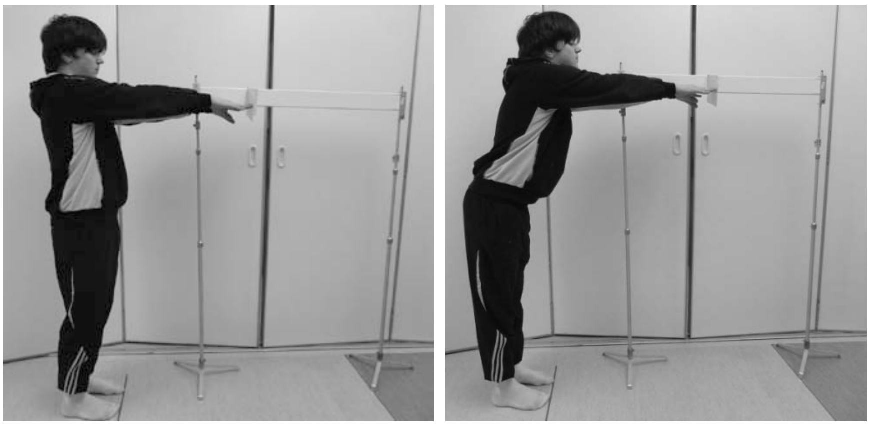

Figure 4. The subject put his/her fingertips (both hands) on a metal plate and then push the metal plate as far as possible by leaning forward without taking a step.

The Full Turn Test (FTT) measures the ability to make a full turn (360°) in both directions. This test is part of the Berg's Balance Test (Berg & Norman, 1996). The number of steps and the time taken to complete a full turn in one place was recorded on a five-level scale (0-4). A low score indicates that the ability to make a full turn is impaired and a high score indicates that the tested person is able to turn 360° safely in four seconds or less. The best attempt of three was recorded.

The Dynamic One-leg Stance Test (DOLS) was developed at the Swedish Development Centre for Disability Sport in Bollnäs, Sweden. The test measures aspects of dynamic and static postural balance on a five-level score (1-5). A higher level is considered more challenging. There were three attempts on each level; to advance to next level, the subject had to complete the lower level satisfactorily. Both legs were tested (Table 2) (Blomqvist & Rehn, 2007).

Table 2. Criteria for the Dynamic One-leg Stance Test (DOLS). The test starts on level one.

Levels	Criteria for each level
One point	The subject is not able to stand on one leg for ten seconds. The scale starts with 1 because subjects who score a zero in the balance test often interpret that to mean failure: “I am worthless and I have no balance ability”.
Two points	The subject is able to stand on one leg for ten seconds, but the subject’s arms, legs, and body moves a lot.
Three points	The subject is able to stand relaxed on one leg for ten seconds without the arms, legs, and body moving.
Four points	Alternative 1: The subject is able to stand on one leg and rotate the trunk with arms in front of the body. The rotation of the body must be at least 90 degrees in total (45 degrees left and 45 degrees right) and executed five times. Alternative 2: the subject must be able to dip the head sideways (lateral flexion of the head) at least five times and the movement must be at least 90 degrees in total (45 degrees left and 45 degrees right).
Five points	The subject is able to do all the former criteria. Then standing on one leg with the opposite foot raised to the level of the top of the toes of the opposite foot for ten seconds.

The One-Leg Stance Test (OLS) evaluates the ability to stand on one leg (reduces BoS) without losing postural balance for as long as possible. The subjects were instructed to stand as still as possible without moving the supporting foot or hooking their free leg on to their supporting leg, which stops the test. A longer time indicates a better static postural balance. The maximum time was set to 30 seconds. The subjects were free to use their arms to maintain their balance. Time was measured (seconds) and the best attempt of three was recorded. The test has been shown to have excellent reliability (Mancini & Horak, 2010).

The Force Platform Test (FPT) was used to determine sway velocity. The force platform (MuscleLab Model ET-FPL-01) was connected to a support device (MuscleLab Model 4000e) and this was connected to a computer for data collection. This set-up enables measurements of the mitigation of the centre of pressure (CoP) generated from the subjects standing on the force platform. The sway velocity of the CoP was used because it has shown to be reliable between test sessions (Salavati et al., 2009; Lafond et al., 2004). The subjects stood on one leg for as long as possible for a maximum of 30 seconds. The sway velocity was calculated based on the time and the total sway. The longest time with the lowest sway velocity from three attempts was recorded. The subjects were instructed to stand as still as possible. Both legs were tested and the subjects were free to use their arms to maintain their balance (Lafond et al., 2004).

Postural balance and muscle strength

Postural balance

The same postural balance tests as in Paper I were used, except that a supplement was added for the OLS and the FPT. For the OLS, standing on one leg blindfolded was added and with the same conditions as mentioned above. This test procedure was done for both legs. For the FPT, several new conditions and positions were added: standing on one leg blindfolded, standing with feet together both eyes open and blindfolded, and semi-standing (one foot in front of the other) both with eyes open and blindfolded. These positions and conditions were recorded in the same way as described above. The new conditions and positions were added to explore whether young people with ID have a more visually dominated postural balance and whether BoS affects their results more compared to their peers without ID.

Muscle strength

The Counter Movement Jump (CMJ) measures the maximum jump height, a measurement that reflects leg muscle strength and power. Standing on a box, the subjects wore a belt around the waist with a string attached. The string was on the other end connected to a measuring device (MuscleLab Model 4000e) that registered the jump height in centimetres. The test person started in an upright standing position, made an initial downward movement by flexing the knees and hips, then without delay extended the knees and hips to jump vertically as high as possible and land on the same spot with arms are held at hip level. Before the jump, the height was measured when the subjects were standing on their toes. This measurement was then subtracted from the actual jump height to calculate the real height of the jump (i.e., the length of the feet was subtracted) (Markovic et al., 2004). The best attempt of three was recorded. The reliability is acceptable (Ortega et al., 2008a)

The Sit-Ups in 30 seconds measures abdominal muscle endurance, requires the subjects to complete as many sit-ups as possible in 30 seconds. The test begins with the subject's back on the floor, the legs bent 90° at the knee joint, the feet flat on the floor, and the hands at the side of the head holding a rope so the elbows point forward. The test leader supported the feet. The subject was asked to raise the upper body until the elbows touched the knees, then return back to the original position. The subject was encouraged to do as many sit-ups as possible in 30 seconds (van de Vliet et al., 2006) and the numbers were counted. The ICC for the Sit-up test is over 0.70 for adolescents (Tsigilis et al., 2002).

The Biering-Sørensen Trunk Extensor Endurance Test (BSTEET) was used to measure endurance in the extensor muscles of the trunk. The subject was prone on a bench with the lower half of the body below the level of anterior superior iliac spines and strapped at three locations – the ankles, the knees, and the buttocks – while resting the arms and the body on a chair positioned in the front. The subjects were then asked to lift their upper body to a neutral alignment position and place their arms across the chest, holding that position as long as possible. If the subject diverted from this position, the subject was requested to return to the neutral alignment position. When the subject could not perform the task, the test was terminated. A stopwatch was used to measure the time in seconds (Latimer et al., 1999). The ICC for BSTEET is over 0.70 (Simmonds et al., 1998).

Postural muscle responses

Postural muscle responses

To evaluate responses in postural muscles, a customised moving platform was used. EMG surface electrodes were placed on the lateral head of the gastrocnemius of the right leg, on the biceps femoris, and on the erector spinae (L4) according to the procedures set by SENIAM (Surface Electromyography for Non-Invasive Assessment of Muscles). The EMG was recorded at 1 kHz with MuscleLab 10 (Ergotest Innovation as), band-pass filtered (10-500 Hz), full-wave rectified, and saved. Muscle onset latency, time-to-peak amplitude, and the ability to adapt the muscle responses after a perturbation were analysed. The platform was moved in a backward translation by 3.5 cm with a peak acceleration of 200 cm/s^2 to produce a forward sway. Six perturbations were done with 30 seconds of rest between each trial. The subjects were not allowed to practice. The first and the sixth perturbations were used to explore muscle onset latency, time-to-peak amplitude (EMG), and the ability to adapt the muscle responses to the perturbation between the first and the sixth trail. The latency of each muscle was identified as the first burst that was > 2 SDs above baseline and was also inspected visually.

Associations between postural stability, physical activity, aerobic capacity and health

Postural stability

The sway velocity was measured when the subject was standing on a force platform (MuscleLab Model ET-FPL-01) for 30 seconds under five sensory conditions: I) feet together (baseline) – all sensory systems are intact; II) feet together blindfolded – the visual sensory system is disturbed; III) feet together standing on Airex mat (2.5 cm) – the somatosensory system is disturbed; IV) feet together standing on Airex mat (2.5 cm) and blindfolded – both the somatosensory and visual sensory systems were disturbed; and V) feet together and rotating the head 30° to the right and 30° to the left with a speed of 60°/second – the vestibular , visual and somatosensory systems were disturbed. To make it easier for the subjects to know how far they should rotate on each side and to help them keep the correct pace, two poles were placed in front of them set at the correct angle. The subjects were instructed to point their nose at each pole in a pace set by a metronome. The subjects were told to stand as still as possible for 30 seconds while being tested. The order of the tests was randomly chosen for each individual to avoid any systematic bias. The lowest sway velocity of three attempts was recorded.

Physical activity

Physical activity level was measured using a pedometer (Keep Walking LS 2000 and LS 7000) for five consecutive days (Sunday through Thursday). The subjects wore the pedometer all the time except when sleeping or if participating in water activities such as swimming or bathing. All subjects received information on how to use the pedometer and instructed to wear it during all activities except while participating in water activities. The subjects who wore the pedometer three days or less were excluded. In addition, the subjects who did not register any results for Sunday were excluded as Sunday was considered an important day because the activity level was different this day in many cases. Former studies have shown that three days of measuring is necessary for valid results (Temple & Stanish, 2009; Tudor-Locke et al., 2005).

Aerobic capacity

To test aerobic capacity, the Åstrand-Rhyming's submaximal ergometer cycle test was used. The test starts by asking the subjects if they take any medications that could affect the test results and how physically active the subjects are in their daily life. On the basis of the interview, an appropriate resistance was chosen. A cycle ergometer with a speed independent cycle (Monark 839 E) was used so a consistent effect could be produced regardless of cadence. This cycle was used because young people with ID often have difficulty keeping a steady cadence while cycling. The test leader set the resistance and set the cadence (50 rpm) using a metronome. The subjects were instructed to keep the cadence as close to 50 rpm as possible. The tested person's pulse was registered each minute with a pulse band (Monark art. no. 9303-95). An estimation of Borg's rate of perceived exertion scale was not used in this study because many people with ID do not understand the meaning of the Borg's scale. Based on the pulse and the resistance, maximum oxygen uptake (l O_2/min) was estimated and a test value (ml O_2/kg x min) was calculated by dividing the estimated VO_2 max by body weight.

Perceived health

The subjects answered five questions about perception of their health, postural balance, physical activity, and aerobic capacity. All questions had a three-step graded scale (Table 3). The first question was about overall health taken from a health questionnaire (Svensson et al., 2012) and the last question was about physical activity taken from a research report about young people with ID in Sweden (Blomdahl & Elofsson, 2011). The remaining questions were constructed by the research group for this study. These researchers are experienced with the target group. To help the subjects with ID, the test leader read the questions and made sure that the subjects understood the meaning of the questions by providing examples.

Table 3. The adapted health questionnaire for young people with ID; five items with three answer alternatives.

How do you grade your overall health condition? Is it		
Good	Not good or bad	Bad
How do you grade your aerobic capacity? Is it		
Good	Not good or bad	Bad
How do you grade your balance? Is it		
Good	Not good or bad	Bad
How do you grade your overall health compared to others your age? Is it		
Better	Not better or worse	Worse
How often do you exercise in your spare time (so much that you break a sweat and get tired) when you are not in school (think about the last month)? Is it		
Never	About once a week	At least twice a week

Procedures

In the reliability and validity study (Paper I), 102 young people with ID volunteered to take part. Nine people were excluded from the study because they did not meet the criteria or lacked their parents'/guardians' consent and four people did not complete the second test (reason unknown). This meant that 89 young people with ID participated. The six balance tests were performed in a randomised order and the retest was carried out in the same order as the first test. The retest was performed between one and twelve days of the first test with a mean gap of 3.3 days (SD 2.8). All tests were done barefoot and no trial run was allowed.

A total of 255 young people joined the postural balance and muscle strength study (Paper II), 102 with ID and 157 without ID. All who volunteered to take part were also allowed to participate in the study. After the interview concerning the verbal exclusion criteria, the subjects were screened for any loss of sensory function in their lower extremities and their vision was checked. As result of these criteria, 100 (40% women) people with ID and 155 (57% women) without ID remained in the study. Two were excluded because they did not meet the criteria and two dropped out without any explanations. Height and weight were measured. The five postural balance tests were performed before the strength tests. The postural balance tests were performed in randomized order. The muscle strength tests were done in the same order for each participant and started with the CMJ, the Sit-ups test, and finally the BSTEET. All tests were performed barefoot and no trial run was done. Six test leaders, two experienced physiotherapists, and four physiotherapy students performed the tests. All test leaders were trained and educated by one of the physiotherapists who was also a test leader. Education and training were done for the test leaders, both through practical performance and theoretical discussions.

For the postural responses study (Paper III), 58 people (females 54%) with ID and 50 people (females 44%) without ID volunteered to participate. More subjects were recruited for the group with ID because of earlier experiences with many dropouts in this group. Before the testing started, two persons with ID and seven persons without ID dropped out. Five of them stated lack of time and two left without any explanations. All subjects were interviewed to determine if they should be excluded according to the established exclusion criteria and screened for any sensory deficit in lower extremities and checked for any visual impairment. Subjects' heights and weights were recorded and ages noted. The subjects stood on a platform that was moved backwards in a surface translation so the subjects swayed forward. Six consecutive perturbations were performed for each subject with 30 seconds of rest between the trials.

For the associations study (Paper IV), 108 young people – 58 individuals with ID (females 54%) and 50 individuals without ID (females 44%) – volunteered to participate. More individuals were recruited to the ID group as we anticipated a larger drop out rate for the reasons mentioned above. Before the testing started, one person with ID and one without ID dropped out without any explanation; 57 young people with ID and 49 young people without ID remained. After questioning and screening for exclusion criteria, the subjects' height and weight were recorded and age noted. Physical activity level was assessed using pedometers for five consecutive days in February. About two months later, the postural balance test was done and aerobic capacity was measured using the Åstrands-Rhyming sub-maximal cycle ergometer test.

Statistical analyses

Reliability and validity

To get a true correlation of 0.85 (Spearman's rho) with a power of 0.80 and a significance level at 0.05 in Paper I, a sample of 46 persons was required to obtain a correlation greater than 0.70. The test-retest reliability for all of the tests, except DOLS, was analysed using the intraclass correlation coefficient (ICC 3,k). The ICC 3,k was selected because the subjects were considered random, but the rater was the same for all the subjects. The ICC is based on a one-way analysis of variance analysis. To visualize the differences between the two test occasions, a

Bland-Altman plot was constructed. The subjects' measurements from the two test occasions were plotted on a graph so any systematic bias or outliers could be seen. To quantify the actual size of the variability between measurements, the standard error of measurements (SEM) was calculated. The SDs for the both tests were multiplied by the square root of one minus ICC: SEM = ICC (SD x√1 -ICC). To easily understand and compare SEM among the tests, SEM was converted to percentages by dividing the mean from the test and re-tests of SEM and then multiplying by 100. By calculating the smallest real differences (SRD), it is possible to see how large a change is required before it can be considered a real change, not a change due to the variation within test or subject. SRD was calculated using the formula 1.96 x SEM x √2. SRD was then converted to percentages (SRD%). To get SRD in percentage, the means from the test and re-tests of SRD were divided and then multiplied by 100. For DOLS, a linear weighted kappa coefficient was used to analyse reliability because DOLS uses an ordinal scale. To check the effect of time between the test and re-retest, the results of subjects with less than four days between the tests were compared to results of subjects with four days or more between the tests.

The concurrent validity between the six tests was analysed using Pearson's correlation coefficient, except for DOLS, then Spearman´s correlation coefficient was used. Significance was set to a p-value <0.05. PEPI Version 4.0 was used to calculate the linear weighted kappa and for the other statistical calculations. SPSS Version 18 (SPSS Inc. Chicago, IL, USA) was used.

Postural balance and muscle strength

It was calculated that 80 persons were needed in each group to detect a difference in the DOLS test between the groups with an odds ratio of 2.0 and power of 80% and a significance level of 5% (a one-sided test). The independent t-test was used to compare means between the two groups except when DOLS was involved. For DOLS, the Mann Witney U-test was used because DOLS uses an ordinal scale. To investigate the effect of removal of the vision input, the ratio of sway velocity was calculated. Feet together with eyes blindfolded was divided by feet together with eyes open, semi-standing blindfolded was divided by semi-standing eyes open, and standing on one leg and blindfolded was divided by standing on one leg eyes open. Then groups and conditions were compared to investigate whether removal of the visual input affected the two groups differently.

To calculate the correlation between postural balance ability, muscle strength, height, and BMI, the Pearson's correlation coefficient was used. Spearman's correlation coefficient was used when DOLS was involved. The significance level was set to a p-value <0.05; however, because of many comparisons (no=15) and correlation analyses (no=21), the significant level was reduced according to Bonferroni. The alpha-value was divided by numbers of comparisons (alpha/n). For difference in means between the groups, significance level was set at 0.003 = 0.05/15, and for correlations analyses between the groups, significance level was set at 0.002 = 0.05/21.

Postural muscle responses

The first perturbation was used to calculate onset latency and time-to-peak amplitude (EMG). To evaluate the ability to adapt the muscle response, the area of the amplitude of each epoch and muscle was calculated (IEMG) after perturbation. The first and the sixth trials were used. An independent t-test was applied to calculate differences in means between the two groups for anthropometrics, onset latency, time-to-peak amplitude (EMG), and IEMG for all three muscles. To analyse whether differences in group structure could have an effect, a correlation analysis was made between sex, height, onset latency, time-to-peak amplitude (EMG), and IEMG for the three muscles. To evaluate whether the p-value altered because of sex or height, a multiple linear regression analysis was made. To identify changes between the first and the sixth trial in onset latency, time-to-peak amplitude (EMG), and IEMG within the groups, a paired samples t-test was used. The level of significance was set to a p-value < 0.05. Analyses were made in SPSS version 19 (IBM).

Associations between postural stability, physical activity, aerobic capacity and health

After a power calculation using variance of postural sway velocity from Paper I, it was determined that 40 individuals were needed in each group to get a power of 80% with a significance level of 0.05. To investigate differences in characteristics of the two groups, an independent t-test was used for height, age, and BMI for female groups and weight, height, and BMI for male groups. Mann-Whitney U-test was used to compare the mean weight for female groups and age for male groups, because the data was not normally distributed. The independent t-test was also used to compare postural stability, level of physical activity, and aerobic capacity. Results from the questionnaire are presented as proportions and a chi-square test was used to test disparity among the groups. For cells containing fewer than five persons, Fisher's exact test was used.

To analyse associations between postural stability, physical activity level, and aerobic capacity, the Pearson's correlation coefficient (r_p) was used for both groups. A multiple linear regression analysis was used to evaluate the dependent variable postural stability influence from the independent variables: level of physical activity, aerobic capacity, and answers from the questionnaire on perceived health. R^2 values were calculated for both groups. Following models were made for both groups:

> *Postural stability* = $a + b_1 *$ *physical activity* + $b_2 *$ *aerobic capacity* + $b_3 *$ *perceived health;*
> *Postural stability* = $a + b_1 *$ *physical activity* + $b_2 *$ *aerobic capacity;*
> *Postural stability* = $a + b_1 *$ *physical activity* + $b_2 *$ *perceived health;* and
> *Postural stability* = $a + b_1 *$ *aerobic capacity* + $b_2 *$ *perceived health.*

Feet close together and standing with eyes open was used to represent postural stability in the multiple linear regressions analysis. Level of physical activity was divided into five groups (steps/day): 1= 0-5000; 2 = 5001-7500; 3 = 7501-10 000; 4 = 10 001-12 500; and 5 = 12 501 and more. Aerobic capacity was divided into five groups (ml O_2/kg*min): 1 = 0-28.0 for women (w) and 0-38.0 for men (m); 2 = 28.1-34.0 w, 30.1-43.0 m; 3 = 34.1-43.1 w, 43.1-51.0 m; 4 = 43.2-48.0 w, 51.1-56.0 m; 5 = 48.1 and more w, 56.1 and more m (Åstrand, 1964). An index from the questionnaire was formed where each question gave a point between 1 and 3. The total sum of the questionnaire index could thus vary between 5 and 15. Five means a high perceived health and 15 means a low perceived health.

The significance level was set to a p-value<0.05. To avoid mass significance for analyses of associations, the alpha-value was divided by the number of comparisons (no=15) according to Bonferroni (alpha = 0.05/15 = 0.003). Calculations were made in SPSS version 20 (SPSS IBM).

Results

Reliability and validity

MFRT had the lowest ICC (0.80) and ETUGT had the highest ICC (0.92). SRD% varied between 12% (ETUGT) and 40.4% (FPT) (Table 4). Bland-Altman plots did not reveal any main systematic bias (see Paper I). The linear kappa coefficient for the DOLS values varied between 0.55-0.69 (Table 5).

The time between the tests had no impact on the results when comparing the subjects who were tested less than four days between the tests with those with four days or more between the tests. The left leg was used for calculation because there was no difference between the legs for the OLS and FPT and the left leg was tested first. The FTT was not calculated because of ceiling effects in both groups.

Table 4. Four postural balance tests (ETUGT, MFRT, OLS, and FPT) and results from two test occasions (Test 1 and Test 2), intra-rater reliability expressed as intraclass coefficient (ICC), standard error of measurement (SEM), and smallest real difference (SRD) between test occasions for young people (16-20 years) with intellectual disability.

Postural balance test n = 89	ETUGT (s)	MFRT (cm)	OLS left (s)	FPT left (mm/s)
Test 1 mean (SD)	12.5 (2.0)	36.4 (5.9)	29.0 (4.0)	36.0 (15.8)
Test 2 mean (SD)	12.4 (1.9)	37.0 (5.1)	28.8 (4.6)	33.9 (15.0)
DB means (SD)	0.14 (0.14)	-0.52 (4.5)	0.24 (2.8)	2.10 (2.8)
ICC	0.92	0.80	0.88	0.89
95% CI	0.88-.95	0.69-.87	0.82-.92	0.84-.93
SEM (%)	0.54 (4.3)	2.46 (6.7)	1.49 (5.2)	5.11 (14.6)
SRD (%)	1.5 (12.0)	6.8 (18.5)	5.11 (14.6)	14.1 (40.4)

CI, confidence interval. DB, difference between, SD, standard deviation.

Table 5. Linear weighted kappa coefficient for the Dynamic One-Leg Stance (DOLS) and results from two test occasions (Test 1 and Test 2) for young people with ID.

n = 89	DOLS left	DOLS right
Test 1 median	4	4
Test 2 median	4	4
Range	1 to 5	1 to 5
Linear weighted kappa (95% CI)	0.69 (0.57-0.81)	0.56 (0.41-0.72)

CI, confidence interval.

For concurrent validity, only some significant associations between the postural balance tests were found; according to Domholdt’s suggestion (Domholdt, 2000), the correlation coefficients for the validity were regarded moderate to little, if any. Moderate correlation was found between OLS and FPT (-0.649) and low correlation between DOLS and FPT (-0.489). The negative correlation depends on a high score on DOLS, and a low score on FPT indicates better postural balance. No significant associations were found between MFRT and the other four balance tests (Table 6).

Table 6. Correlation coefficients between five balance tests (ETUGT, MFRT, DOLS, OLS, and FPR) used for young people (n=89) with intellectual disability.

Balance test	ETUGT	MFRT	DOLS left	OLS left	FPR left
ETUGT	-				
MFRT	-0.051 b	-			
DOLS left	-0.254 a*	0.102 a	-		
OLS left	-0.027 b	0.042 b	0.326a*	-	
FPT left	-0.037 b	-0.086 b	-0.489 a*	-0.649 b*	-

a) Spearman's correlation coefficient. b) Pearson's correlation coefficient. * significant at a level of 0.05. ETUGT, Extended Up and Go test; MFRT, Modified Forward Reach test; DOLS, Dynamic One-Leg Stance; OLS, One Leg-Stance; FPT, Force Platform Test.

Postural balance and muscle strength

For OLS when not blindfolded, a ceiling effect was seen in both groups, so OLS was not calculated. Young people with ID performed significantly lower on almost all postural balance and muscle strength tests but with one exception: FPT with feet together and eyes open and FPT with feet together and blindfolded (Table 7 and 8).

Table 7. Results from the Dynamic One-Leg Stance (DOLS) for young men and women with and without intellectual disability (ID). A score of 1 reflects a lower performance while a score of 5 reflects a higher performance for DOLS.

	DOLS Left	DOLS Right	DOLS Left BF	DOLS Right BF
Men				
ID (n=60)				
Median (max-min)	4 (3-5)	4 (1-5)	2 (1-5)	2 (1-4)
Non-ID (n=67)				
Median (max-min)	5 (4-5)	5 (4-5)	3 (2-5)	3 (2-5)
p-value	<0.001	<0.001	0.002	<0.001
Women				
ID (n=40)				
Median (max-min)	4 (1-5)	4 (1-5)	2 (1-4)	2 (1-4)
Non-ID (n=88)				
Median (max-min)	5 (3-5)	5 (3-5)	3 (1-5)	3 (1-4)
p-value	<0.001	<0.001	<0.001	<0.001
Total				
ID (n=100)				
Median (max-min)	4(1-5)	4(1-5)	2(1-5)	2(1-4)
Non-ID (n=155)				
Median (max-min)	5(3-5)	5(3-5)	3(1-5)	3(1-5)
p-value	<0.001	<0.001	<0.001	<0.001

BF, Blindfolded.

Low but significant correlations between MFRT and height were observed for both groups (r=0.35-0.45) (p<0.001). There were also low correlations between MFRT and all strength tests for the non-ID group (r=0.25-0.36) (p<0.002). ETUGT showed low correlations between CMJ and Sit-Ups (r = 0.32-0.34) (p=0.001) for the ID group but not for the non-ID group. There were also low correlations between OLS on the left side and blindfolded and CMJ, Sit-Ups, and BSTEET for the ID group (r = 0.26-0.30) (p=0.001 to p<0.001). OLS for the right side when blindfolded showed low correlations with CMJ and Sit-Ups for both groups (r=0.26-0.39) (p=0.001 to p<0.001). No associations were obtained between FPT and the three muscle strength tests (Table 9).

Postural muscle responses

A moderate correlation between sex and height was achieved (0.643 $p<0.001$), but there were no other significant associations between sex, height, onset latency, time-to-peak amplitude (EMG), and IEMG for the three muscles. The p-values for the groups for onset latency, time-to-peak amplitude (EMG), and IEMG for the three muscles did not alter because of sex and/or height in the linear regression analyse. Therefore, the analyses were not further subdivided (stratified) into males and females.

No difference in onset latency between the two groups (ID and without ID) and no changes in onset latency between the first trial and the sixth trial within the groups could be found. For time-to-peak amplitude (EMG) in the three muscles, there were no significant distinctions between the two groups except that young people with ID had slower time-to-peak amplitude (EMG) in the biceps femoris in the first trial compared to peers without ID (156.9 vs. 143.4; $p=0.041$). Young people with ID significantly reduced the time-to-peak amplitude between the first and the sixth trail for all three muscles, but young people without ID significantly reduced only time-to-peak amplitude between the first and the sixth trial in the gastrocnemus (Table 10).

The two groups used the same muscle synergy, a pure ankle strategy. First muscle to react was gastrocneminus with a mean onset time about 70 ms, biceps femoris came second approximately 30 ms later and further 30 ms before erector spinae in the lumbar region (Table 10). Two subjects in both groups used mixed strategies in the first trial, and two subjects with ID and three subjects without ID used mixed strategies in the sixth trial.

Table 10. Muscle onset latency and time-to peak-amplitude (EMG) in milliseconds (ms) after repeated external perturbations (support surface translation backwards) in lateral gastrocnemius, biceps femoris, and erector spinae (lumbar region L4) for young subjects with and without intellectual disability (ID).

	Subjects with ID (n= 56) Females=30 Males=26	Subjects without ID (n=43) Females=19 Males=24	p-value (between groups)
	Mean (SD)	Mean (SD)	
gastrocnemius			
onset latency trial 1	70.6 (13,8)	73,2 (11.6)	0.321
onset latency trial 6	68.0 (12.2)	71.1 (12.6)	0.222
p-value (between trials)	0.217	0.427	
time to peak (EMG) trial 1	129.3 (26.5)	128.4 (23.8)	0.869
time to peak (EMG) trial 6	120.4 (16.4)	118.6 (16.6)	0.604
p-value (between trials)	0.024*	0.013*	
biceps femoris			
onset latency trial 1	103.2 (12,7)	102.8 (9.3)	0.859
onset latency trial 6	101.1 (12.1)	105.6 (12.3)	0.079
p-value (between trials)	0.292	0.130	
time to peak (EMG) trial 1	156.9 (37.7)	143.4 (26.2)	0.041*
time to peak (EMG) trial 6	137.3 (26.0)	143.1 (28.1)	0.299
p-value (between trials)	0.001*	0.935	
erector spinae (L4)			
onset latency trial 1	135.4 (17.0)	132.6 (17.0)	0.440
onset latency trial 6	132.0 (15.0)	129.2 (11.9)	0.351
p-value (between trials)	0.166	0.935	
time to peak (EMG) trial 1	172.4 (31.9)	176.2 (26.7)	0.526
time to peak (EMG) trial 6	161.1 (23.8)	167.0 (30.9)	0.300
p-value (between trials)	0.033*	0.120	

*Significance level was set to a p-value of less than 5%.

Both groups significantly decreased the mean IEMG activation between the first and the sixth trial in two of the epochs (70-149 ms and 150-249 ms) and in all three muscles except for one epoch (70-149 ms) for the erector spinae L4. Young people with ID decreased their IEMG activation less compared to peers without ID. This pattern was not significant except for gastrocnemius epoch (150-249 ms) (356.3 vs. 173.9; p=0.005). An exemption from this pattern was found in biceps femoris epoch 150-249 ms, where young people with ID decreased activation more compared to peers without ID, but this was not statistically significant (Table 11).

Table 11. Comparisons between young people with and without ID and their ability to adapt the IEMG (total micro volt during epoch) response from the first to the sixth external perturbation in three muscles and epochs.

	Subjects with ID (n= 56) Females=30 Males=26	Subjects without ID (n=43) Females=19 Males=24	p-value
	Mean IEMG (SD)	Mean IEMG (SD)	
gastrocnemius			
epoch (0-69 ms) 1	55,4 (110.6)	43.4 (101,8)	0.573
epoch (0-69 ms) 6	64.6 (107.4)	59.4 (84.6)	0.799
p-value (Change in %)	0.596 (nc)	0.388 (nc)	
epoch (70-149 ms) 1	2677,2 (1676.6)	3292 (2199.4)	0.118
epoch (70-149 ms) 6	2263.2 (1530.8)	2128.6 (1363.0)	0.650
P-value (Change in %)	0.007* (↓15%)	<0.001* (↓35%)	
epoch (150-249 ms) 1	1391.4 (1040.8)	1212.0 (1256.6)	0.439
epoch (150-249 ms) 6	712.6 (727.8)	347.8 (458.6)	0.005*
p-value (Change in %)	<0.001* (↓49%)	<0.001* (↓72%)	
biceps femoris			
epoch (0-69 ms) 1	-8.6 (50.8)	1.2 (56.4)	0.369
epoch (0-69 ms) 6	- 15.4 (50.6)	- 11.8 (109.0)	0.829
p-value (Change in %)	0.407 (nc)	0.469 (nc)	
epoch (70-149 ms) 1	1392.0 (1183.8)	1249.0 (996.2)	0.530
epoch (70-149 ms) 6	1042.4 (859.0)	832.0 (881.2)	0.240
p-value (Change in %)	0.011* (↓26%)	0.015* (↓33%)	
epoch (150-249 ms) 1	2116.8 (1812,6)	1590.0 (1410.6)	0.096
epoch (150-249 ms) 6	874.0 (784.0)	905.6 (926.6)	0.856
p-value (Change in %)	<0.001* (↓59%)	<0.001* (↓43%)	
erector spinae (L4)			
epoch (0-69 ms) 1	-22.4 (86.4)	-11.8 (115.4)	0.613
epoch (0-69 ms) 6	- 21,4 (114.4)	13.4 (85.6)	0.105
p-value (Change in %)	0.955 (nc)	0.227 (nc)	
epoch (70-149 ms) 1	446.2 (554.4)	460.8 (556.0)	0.899
epoch (70-149 ms) 6	362.4 (530.8)	313.6 (372.0)	0.617
P-value (Change in %)	0.135 (↓19%)	0.051(↓32%)	
epoch (150-249 ms) 1	2046.0 (1504.0)	1924.4 (1404.6)	0.688
epoch (150-249 ms) 6	1469.4 (1280.8)	1059.2 (776.4)	0.055
P-value (Change in %)	0.002* (↓28%)	<0.001*(↓45%)	

↓= reduction in IEMG activation in percent between the first and the sixth trail. Significance level was set to a p-value of less than 5%.

Associations between postural stability, physical activity, aerobic capacity and health

Females without ID took more steps than females with ID, and males with ID took more steps than males without ID. Young people with ID tended to have higher postural sway velocity than young people without ID (Table 12).

Table 12. Level of physical activity tested with pedometer (average steps taken/day) and sway velocity (mm/s) on a force platform in young females and males with and without intellectual disability (ID).

	Females with ID	Females without ID	p-value	Males with ID	Males without ID	p-value
Average steps taken/day						
	n=29	n=20		n=24	n=27	
	8157(3455)	12089(4152)	0.001	10399(4277)	9833(3596)	0.610
Postural sway (mm/s)						
	n=30	n=19		n=26	n=24	
FT	11.4 (2.7)	10.5 (2.3)	0.230	13.5 (4.9)	9.8 (2.1)	0.001
FT BF	19.1 (5.9)	17.5 (4.6)	0.322	23.9 (9.3)	17.8 (4.9)	0.006
FT SM	16.2 (4.8)	13.4 (3.3)	0.034	17.9 (6.0)	12.7 (2.1)	<0.001
FTBFSM	38.6 (19.6)	33.3 (7.0)	0.258	39.5 (13.4)	27.8 (4.8)	<0.001
FT HR	17.9 (6.3)	15.5 (4.2)	0.147	18.6 (5.8)	13.9 (2.5)	0.001

Means (standard deviations); FT=Stand with feet close together; SM=Soft mat; BF=Blindfolded; FT HR= Stand with feet close together while rotating the head 30° to the left and right with a speed of 60°/seconds; n, number of subjects in group; Significance level was set to a p-value of less than 5%.

Both males and females with ID had significantly lower scores of estimated maximum oxygen uptake compared to males and females without ID (p=0.004, males; p<0.001, females). The ID group also had significantly lower scores for test values compared to the group without ID (p=0.012, males; p<0.001, females) (Table 13).

Table 13. Estimated maximum oxygen uptake (VO_2max); a comparison with independent t-test between young people with intellectual disability (ID) and young people without ID.

	VO_2max (l O_2/min):	Test value (ml O_2/kg*min):
Females with ID n=30	2.0 (0.4)	30.7 (8.5)
Females without ID n=19:	2.6 (0.4)	39.7 (6.7)
p-value:	<0.001	<0.001
Males With ID: n=23	2.6 (0.5)	36.5 (9.6)
Males Without ID n=23	3.3 (1.0)	45.4 (13.3)
p-value:	0.004	0.012

Means and standard deviations for normal distributions. p-value corresponds to differences between groups with and without ID; n, number of subjects in group.

Females estimated their health lower than males and this applied for both people with and without ID. Fifty-five percent of the females and 82% of the males rated their health as good. The trend for the answers on the questions was that people with ID more often estimated them as good, for aerobic capacity and postural balance compared to people without ID. A higher percentage of the subjects with ID said that they never did any physical exercise compared to the subjects without ID (females ID=27% vs. females non-ID=5% and males ID=16% vs. Males non-ID=0%) (Table 14).

Table 14. Distributions (%) of answers from a health questionnaire for young females and males with and without intellectual disability (ID).

	Female ID n=30	Female non-ID n=19	p-value	Male ID n=25	Male non-ID n=24	p-value
Self rated overall health:						
Good	50	63		76	88	
Not good or bad	50	26	0.063	24	12	0.463
Bad	0	11		0	0	
Self rated aerobic capacity:						
Good	50	26		76	65	
Not good or bad	40	63	0.268	20	27	0.278
Bad	10	11		4	8	
Self rated balance:						
Better	56	37		56	42	
Not better or worse	37	53	0.448	44	58	0.396
Worse	7	10		0	0	
Self rated health when comparing to peers their own age:						
Better	50	26		60	46	
Not better or worse	50	58	0.043	36	50	0.686
Worse	0	16		4	4	
Number of times of exercising per week:						
Never	27	5		16	0	
Once a week	26	11	0.033	16	29	0.109
At least twice a week	47	84		68	71	

p-value correspond to differences between ID and non-ID groups calculated by Fisher's exact test.
n, number of subjects in the group.

No significant associations could be seen between postural stability and level of physical activity and postural stability and aerobic capacity in females and males with or without ID (Table 15).

Table 15. Associations between postural stability tests, level of physical activity (steps per day) and estimated maximal oxygen uptake (VO_2max) and test value for young females and males with and without intellectual disability (ID).

Stability parameters	Steps per day		VO_2max (l O_2/min):		Test value (ml O_2/kg*min):	
	r_p	p-value	r_p	p-value	r_p	p-value
Females ID	n=28		n=30		n=30	
FT	-0.175	0.374	-0.087	0.646	0.016	0.935
FT BF	-0.263	0.176	-0.103	0.589	0.041	0.831
FT SM	-0.011	0.955	-0.055	0.772	0.169	0.372
FT BF SM	-0.059	0.767	0.006	0.976	0.019	0.921
FT HR	-0.098	0.619	0.280	0.133	0.370	0.044
Females non-ID	n=18		n=19		n=19	
FT	0.049	0.846	0.162	0.508	0.196	0.422
FT BF	-0.060	0.812	-0.010	0.966	0.051	0.835
FT SM	0.141	0.577	0.036	0.883	0.045	0.856
FT BF SM	-0.152	0.546	0.261	0.281	0.154	0.530
FT HR	0.173	0.492	-0.026	0.915	0.054	0.827
Males ID	n=26		n=23		n=23	
FT	-0.226	0.189	0.154	0.483	-0.156	0.477
FT BF	-0.047	0.820	0.104	0.636	-0.101	0.647
FT SM	-0.153	0.456	-0.065	0.769	-0.191	0.384
FT BF SM	-0.204	0.318	-0.063	0.776	-0.205	0.348
FT HR	-0.383	0.053	-0.031	0.887	-0.134	0.541
Males non-ID	n=24		n=23		n=23	
FT	-0.158	0.460	0.177	0.420	0.170	0.438
FT BF	-0.179	0.403	-0.146	0.505	-0.173	0.430
FT SM	-0.137	0.523	0.057	0.797	0.126	0.566
FT BF SM	-0.327	0.119	-0.378	0.075	-0.353	0.099
FT HR	-0.148	0.491	-0.152	0.489	-0.212	0.331

p-value corresponds to correlations between balance tests and physical activity and aerobic capacity. FT=Stand with feet close together; BF=Blindfolded; SM= Soft matt; r_p=Pearson's correlation coefficient.

The results of the multiple linear regression analysis demonstrated that the model with all independent variables – physical activity, aerobic capacity, and answers from the questionnaire effects on postural stability – was explained by 5.7% (p-value=0.431) for young people with ID (n=50) and by 17.4% (p-value=0.067) for young people without ID (n=41). Analysis of two of the independent variables – aerobic capacity and health questionnaire – showed that the variance of postural stability could be explained by 15.4% (p-value=0.038) for young people without ID. No other significant explanations were found for combinations of two independent variables.

Discussion

The ICC was high for four of five evaluated balance tests. The SRD% were considered low for ETUGT and MFRT (Flansbjer et al., 2005), and those tests are proposed to be used for evaluating changes in postural balance over time. The concurrent validity between the six tests was low, indicating that various tests need to be used to establish different aspects of postural balance.

Young people with ID performed poorer on several postural balance tests – ETUGT, MFRT, and OLS – compared to age-matched controls without ID. These results suggest that young people with ID have impaired postural balance in many aspects. Young people with ID also performed worse on muscle strength tests – CMJ, Sit-Ups, and BSTEET – compared to peers without ID, a finding that suggests that their legs and trunk muscles are weaker than their age-matched peers. Only low correlations could be found between postural balance tests and muscle strength tests, BMI, and height. Young people with ID did not have a more visually dominated postural balance compared to peers without ID, a hypothesis proposed by some clinicians based on their experience with young people with ID.

No significant differences were found in onset latency and time-to-peak amplitude (EMG) in the gastrocnemius, the biceps femoris, and the erector spinae (L4) after external perturbations between young people with and without ID. Both groups mainly used an ankle strategy after perturbations. The mean IEMG activation between the first and the sixth perturbations decreased in both groups and young people with ID tended to decrease their IEMG less than peers without ID, a finding that suggests that young people with ID were not able to adapt as readily as their peers.

No significant associations were found between postural stability tests, level of physical activity, and aerobic capacity for young people with and without ID. Females with and without ID rated their health lower than males with and without ID rated their health.

Reliability and validity

The ICC is one of the recommended test-retest correlation coefficients. Schuck and Zwingmann (2003) suggest that to address the response stability of tests and to determine the smallest detectable change for a test, the SEM% and SRD% should be used (Schuck & Zwingmann, 2003). According to Fleiss criteria (Fleiss, 1981), ETUGT, OLS, and FPT has excellent test-retest reliability and MFRT has good reliability.

To the author's knowledge, only one study – Villamonte et al. (2010) – has addressed the reliability of balance test for people with ID. Villamonte et al. explored the reliability of 16 balance tests such as

ETUGT, FRT, and OLS. The study subjects (n=16) were people with Down's syndrome (DS) between 5 and 31 years old. This small study sample was further divided into four subgroups – boys (n=4); girls (n=7); men (n=6); and women (n=4). As the test subjects were a specific subgroup of people with ID (people with DS) and the sample size was relatively small (n=16), it is difficult to compare their results with the results presented in this thesis. Villamonte et al. (2010), however, found that ETUGT had low ICC values (0.22-0.24). On the other hand, Zaino et al. (2004) found that ICC was excellent for the Timed Up and Go Test in young people (8 to 14 yrs) with cerebral palsy. Although the study examined young people, it is difficult to compare the studies because cerebral palsy can result in motor disorders, which is not the case for ID. The results are in line with our reliability results and suggests that the ETUGT is a reliable tool for both young people with cerebral paresis and young people with ID. The extended version of this test was used because earlier it had been used on people with ID and Wall et al. (2000) believe the extended version better isolates function deficits and therefore helps clinicians develop prevention strategies, guiding both treatment and further testing (Wall et al., 2000). To detect a true change in ETUGT for young people with ID, the value must change at least by 12% or 1.5 seconds from the first test. Other studies have demonstrated SRD% values between 23% and 34%, but they used the shorter Timed Up and Go test and tested elderly people and patients with stroke or Alzheimer's diseases (Flansbjer et al., 2005, Mangione et al., 2010, Ries et al., 2009).

The ICC for OLS have been reported to vary between 0.75 to 0.85 for elderly people with and without disabilities (Giorgetti et al., 1998). The ICC values for the DS study were between 0.57-0.94, which is similar with or little bit lower than for young people with ID. SRD% for OLS was 14.1 % or 4.1 seconds before it could be considered a true change, which is regarded as low.

Watanatada et al. (2006) found an ICC between 0.69 and 0.83 for OLS measuring the total sway path on a force platform for individuals between 40 and 60 years old without ID. Demura et al. (2008) established ICC values between 0.94 and 0.97 when measuring sway velocity on a force platform with feet together for 30 seconds for young adults and elderly. Our results for young people with ID are in line with Demura et al. (2008), but higher than what Watanatada et al. (2006) found. For FPT, the SRD% was 40.4%, which is high. Salavati et al. (2009) found SRD% of 18% for individuals with musculoskeletal disorders standing with feet together and measuring sway velocity for 30 seconds (Salavati et al., 2009). The reason for the high SRD% in our study could depend on that when measuring more unstable positions it also gives a higher SRD%.

In DS, the ICC varied between 0.25 and 0.73 for FRT (Villamonte et al., 2010). Two other studies have reported ICC levels between 0.73 and 0.98

for people with Parkinson's disease and children with and without Cerebral palsy (Zaino et al., 2004, Steffen & Seney, 2008), and those results are in line with what has been found for young people with ID even when the modified version of FRT was used. Steffen and Seney (2008) found that the SRD% for FRT for patients with Parkinson's disease was 42%, a percentage higher than what we found in our reliability and validity study (SRD% of 18.5% or 6.8 cm).

The linear kappa coefficient was regarded as fair to good for the DOLS according to Fleiss (1981). The low reliability for DOLS compared to the other balance tests may be due to the fact that a subjective rating is done. This could lead to different judgement of the postural balance when the subjects that are tested is between two levels, even if the test has rather objective and clear levels /divisions.

The concurrent validity between the tests varied from moderate to none. A moderate to low correlation was found between DOLS, OLS, and FPT. Between DOLS and ETUGT, only a low correlation was found which could be explained by that both these tests relate to some dynamic components of postural balance. None of the balance tests had any correlation with MFRT and this could depend on that MFRT measures the ability to shift the centre of mass without losing the balance, which is a specific function of the postural balance system, somewhat different from static and dynamic.

Postural balance and muscle strength

All the postural balance tests that were used have been reported to be reliable for this group (Blomqvist et al., 2012). All subjects could stand on one foot for 30 seconds (OLS eyes open), and this was a better result compared to what a Finnish study found (Lahtinen et al., 2007) using the Stork test on young (17-22 years) people with ID. Even if OLS and Stork test is not done exactly the same way, both tests measure the ability to stand on one foot. There are some differences in the design between the tests that could explain the dissimilarity. In the Stork test, the test person stands on one foot with their hands on their hips and their free leg and foot against the supporting leg; in the OLS test, the test person can use their arms and leg to help to maintain balance.

Suomi and Koceja (1994) found that adults with ID had significantly more lateral sway compared to adults without ID and Dellavia et al. (2009) reported that athletes (20-30 years) with ID had greater mean body sway than controls without ID, findings that are in line with our results. In contrast, Carmeli et al. (2008) reported less sway for adults with ID compared to adults without ID. The small size (n=15) could explain this difference as the small sample size could have been insufficient to cover the true variations of the investigated population. Carmeli et al. (2008) also reported that the ratio between EO and BF sway area increased more for the control group than the ID group and this was also reported by Dellavia et al. (2009) that the ratio between EO and BF sway rate (mm/s) was increased more for the control group. The result in the postural balance and muscle strength study supports Carmeli et al.'s (2008) and Dellavia et al. (2009) findings that subjects with ID do not have more visually dominated postural balance than subjects without ID, but, as stated earlier, the sample size was small in the study by Carmeli et al (2008).

For ETUGT, a significant difference between the groups was found, but it was only 1 second, a difference that could be so small that its clinical value could be questioned. Carmeli et al. (2003) found that a group of people with mild ID and with a mean age of 60 years performed the ETUGT six seconds slower than a control group without ID (Carmeli et al., 2003). For MFRT, a significant difference of 5.5 cm between the groups was also found in the postural balance and muscle strength study. When comparing with two other studies that explored the results from the Forward Reach test for adults (aged 41-69), it was revealed that adults with ID performed more than 10 cm shorter than adults without ID (Carmeli et al., 2005, Duncan et al., 1990). It appears as if people with ID have reduced postural balance already at a young age compared with peers. This reduction in postural balance increases with age (Lahtinen et al., 2007), findings that indicate the need to address the situation at an early age.

Studies have reported that obese and high BMI could impact postural balance for males and prepubertal boys (Handrigan et al., 2010; Deforche et al., 2009). No correlation between BMI and postural balance could be found. This finding, however, could have been due to the fact that the mean BMI (between 22.4 and 25.0) was within normal classification for young people under 18 years. No association between muscle performance and body sway was found and this was in line with what Granacher and Gollhofer found for adolescents without ID (Granacher & Gollhofer, 2010). Wiacek et al., (2009) found associations between muscle strength in low body part and postural balance for elderly women. Some low associations between muscle strength tests and postural balance tests were found in our study, but muscle strength seems not to have any great importance for postural balance for young people. Women had lower sway than men. The reasons for this is not known, further studies are needed to examine these sex difference.

Postural muscle responses

No difference in onset latencies was found. For children (4-6 years) with DS, a delayed onset latency in the gastrocnemius and the hamstrings was found after perturbation compared to peers. This delay could depend on slow central processing (Shumway-cook & Woollacott, 1985). Hale et al. (2009) found that adults with ID (mean 58 years) had slower latency (force response in leg) compared to adults without ID (mean 49 years) after external perturbation. The authors speculated that this slower latency could be the result of age differences between the two groups and the mean results for adults with ID were similar with those reported as normative (Nashner, 1997). If this is the case, Hale et al.'s (2009) results are in line with what was found in this thesis. It seems that people with ID and without DS have the same onset latency as people without ID.

To our knowledge, this was the first study of time-to-peak amplitude (EMG) after backward perturbations. The results suggest that people with ID have problems predicting the right muscle response after the perturbation and have significantly reduced the time-to-peak in all three muscles, but young people without ID only reduced time-to-peak in the gastrocnemius. This difference could be influenced by the fact that young people with ID have difficulties processing sensory information from the somatosensory system, so they need more time to correct the time-to-peak amplitude (EMG). de Freitas et al. (2010) investigated the time-to-peak amplitude in the opposite direction with forward perturbations and analysed different muscles. They found that the tibialis anterior was activated first and then the rectus femoris. However, the rectus femoris, which is more proximal, reached its peak before the tibialis anterior (de Freitas et al., 2010). This finding was not evident in our study where time-to-peak amplitude (EMG) followed the onset latency with a delay of about 29-59 ms in a distal to proximal order. Further studies of responses for backward and forward perturbations are necessary.

Several studies have reported adaptation of muscle responses after repeated perturbations (Keshner et al., 1987, Horak & Nashner, 1986, Horak et al., 1989) and it seems that the largest adaptation is between the first and the second perturbation (Oude Nijhuis et al., 2009). This finding agrees with the results for both groups in our study even if the comparison was between the first and the sixth trail. The IEMG area in the different epochs did not significantly vary between the groups. However, young people with ID reduced their IEMG area less compared to young people without ID in most of the epochs between the trials (1 and 6). Cerebellum is known to control adaptions of postural balance responses (Shumway-Cook & Woollacott, 2012) and Nashner (1976) found that people with cerebellar deficits had difficult to adapt their long-latency reflex gain after repeated disturbances of postural balance. It appears that the nervous system prioritizes somatosensory inputs to control postural sway when imbalance is caused by rapid displacement of the supporting surface (Shumway-Cook and Wollacott, 2012). Perhaps, young people with ID adapt their IEMG activations less because they have difficulties processing the information from the somatosensory system in the CNS, a deficit that could lead to slower adaptation of the muscle response. Vision and somatosensory inputs seem to be the most important inputs for maintaining a quiet stance (Shumway-Cook & Wollacott, 2012), and a supporting fact for the inability to use somatosensory information is that young people with ID have more postural sway than peers without ID, which is not affected by vision (eyes open or closed) (Blomqvist et al., 2013).

Lin and Woollacott (2002) compared unstable older adults (mean=76 yrs) with younger adults (mean=25 yrs) for postural response amplitudes (IEMG) after perturbation. They found that after a perturbation unstable older people used 60% and young adults used 40% of their maximum capacity of the gastrocnemius (Lin & Woollacott, 2002). Their conclusion was that decreased muscle contraction capacity could be a limiting factor in performance of balance-related tasks. In addition, young people with ID have significantly reduced strength compared to peers (Blomqvist et al., 2013) and could therefore potentially use a higher percentage of their maximal. This was not investigated in this study because people with ID have difficulties to do a specific maximum muscle contraction on command.

Associations between postural stability, physical activity, aerobic capacity and health

There were no associations between static postural balance, aerobic capacity, or level of physical capacity in young people. No studies have investigated the association between these three components for young people. However, Mikaelsson (2012) found a significant association between aerobic capacity and self-reported physical activity for young people. Several studies have investigated this association for older physically active persons without ID and the results also show low associations (Hayashia et al., 2012, Hughes et al., 1996 and Spagnuolo et al., 2010). One of the studies did not find any association, but found that elderly people (>60 years old) with higher aerobic capacity had a better postural balance and a higher P-ADL (Personal activity in daily life) (Hayashia et al., 2012). Spagnuolo et al. (2010) found an association between walking ability, measured using a shuttle walk test, and their ability to maintain postural balance, measured using the Timed Up and Go Test and the Berg's balance scale. Voelcker-Rehage et al. (2010) found a strong association between cardiovascular fitness, balance and cognitive functioning in elderly persons, and Kuh et al. (2009) reported that higher cognitive scores in childhood and adulthood were associated with better standing balance (Kuh et al., 2009). The studies on older people may not be suitable for comparison with young people because age affects the body – as people age, their strength, nerve conduction velocity, and vision worsen (Swedish National Institute of Public Health, 2010).

Different sensory subsystems for postural balance (vision, vestibular, and somatosensory system) were challenged during the postural stability tests, and this was measured on a force platform. The mean velocity of the mitigation of CoP was used for analyses and it has been shown to have high reliability (Salavati et al., 2009 and Lafounf et al., 2004). One reason for not finding any associations might be that the postural stability tests were static and there might be a limited carry-over effect from the dynamic postural balance task. A problem with dynamic balance tests is that they are difficult to execute, especially for persons with ID. Another reason why there were no associations could be that young people might have a high capacity for static postural balance tasks, a characteristic that could lead to a ceiling effect.

Baynard et al. (2008) reported that there were no differences in aerobic capacity for young people with ID (16-21 years old) compared to peers. On the contrary, Wallén et al. (2009) found that young people with ID (mean 18.6 years) had lower aerobic capacity than an age-matched control group. This was also found by Salaun and Berthouze-Aranda (2012). Our study's finding that young people with ID generally have lower aerobic capacity than peers is in line with the results from those two studies.

In the questionnaire, the females with ID rated their level of activity lower than females without ID. The difference was significant and the finding fits with the results of the more objective pedometer test. When the subjects rated their aerobic capacity in the questionnaire, no differences were seen between the groups (ID and non-ID), but the result of the aerobic capacity test exposed that the group with ID had significantly lower aerobic capacity than the group without ID. Both females and males in the ID group rated their balance ability as good more often than the control group; however, this self-rated evaluation was contradicted by the postural stability tests. It seems that young people with ID have difficulty rating their physical abilities.

On the whole, the multiple linear regression model had no statistically justified explanation for the postural stability for young people; however, for young people without ID, two of the independent variables (aerobic capacity and questionnaire index) had some statistically significant effects on postural stability. One reason for the difference between the groups could be that young people with ID overestimated their health, aerobic capacity, and postural balance in the questionnaire, so they received a lower index than young people without ID. However, this does not explain the influence of aerobic capacity. As young people with ID have lower aerobic capacity and young women with ID are less physically active than peers, this call for measures.

Methodological considerations

The results in this thesis cannot be generalised to people with severe or profound ID, because they would find it more difficult to understand instructions and they have more physical disabilities than people with mild to moderate ID. Although the subjects in this thesis were young, it should be possible to apply the results to adults with mild to moderate ID, because ID does not change with age. However, ageing will play a role, so the results probably cannot be applied for elderly people with ID.

Even if the ICC were high for many of the balance tests, the inter-rater reliability is not known. To improve the inter-rater reliability, all test leaders were trained and educated which included realistic performances and dialogue on consensuses about the postural balance tests. This should have eliminated any influence of an incongruent inter-rater reliablility.

For the OLS test with eyes open, many of the subjects reached the maximum time of 30 seconds. For young people, it seems that the test is too easy. One way to make the test more difficult is to extend the time, but there is a risk that the measure will be influenced by fatigue in the foot muscles. Another way to make it more difficult is to let the participants stand on foam surface, but proprioception inputs might influence the results. Nevertheless, the OLS could be performed in many ways and there is no consensus in the literature about how this test should be performed. The test was performed with arms hanging freely because that is the normal situation in daily life. Many subjects reached scores of 4 or 5 on DOLS with eyes open, results that led to a ceiling effect. Because of the low reliability and the ceiling effect, this test needs to be developed further if it is to be used to measure the postural balance of people with ID.

The two groups that were compared for postural muscle responses did not match each other for sex and heights. However, an analysis showed that these differences did not affect the results. Therefore, it was decided to do the analyses on the whole group without using any subgroups. To avoid uncertainties of the amplitude using EMG, a normalisation to a preference value (e.g., maximum voluntary contraction) could have been done, but this was not done because people with ID have difficulties performing specific maximum voluntary contractions. Furthermore, muscle tone was not measured because it was not expected to find any difference in muscle tone between the groups as the neurological screening did not expose any difference and the baseline measurements uncovered no visual differences in EMG activity.

A pedometer was used to measure physical activity because it is cheap, easy to use, and easy to understand. Pedometers, however, have some limitations: a pedometer does not register water activities or upper limb activities such as strength training for the upper body or horse riding. In addition, merely shaking a pedometer can produce inaccurate results. To avoid these issues, the participants and staff were given specific instructions and training on how to use the pedometer.

The Åstrand-Rhyming submaximal cycle ergometer test was used to estimate aerobic capacity. Another study – Wallén et al., 2009 – that used this test on young people with ID had similar results as we did (i.e., lower estimated maximal oxygen uptake). The test is considered to have high validity and reliability on a group level (Noonan & Dean, 2000). As people with ID often struggle to maintain a set pace, a speed dependent cycle was used, which means that the breaking effect is consistent no matter how fast or slow the pedals are moving. This feature made it possible for many in the ID group to perform this test satisfactorily. The test was carried out according to a manual, with the exception of not including the Borg's rating of perceived exertion scale because it was difficult for persons with ID to make an assessment of their experienced exertion.

Parts of the health questionnaire have been tested for validity. Questions about overall health have good validity on a typical population (Lundberg & Manderbacka, 1996). However, it has not been tested on persons with ID. The other four questions have not been tested for validity or reliability, which is a limitation of the study, but questions about physical activity have been used for young people with ID (Blomdahl & Elofsson, 2011). The health questionnaire had few answering alternatives to make it easier for persons with ID to answer. If the participant requested further explanations, the questions were verbally explained in an attempt to make the questions more easily understood. A study on adults with ID showed that questionnaires used to assess physical activity level have an uncertain validity (Matthews et al., 2011). Persons with ID might find it hard to rate their health due to their reduced ability to reason and think abstractly (WHO, Guide for mental retardations, 1996). The gained knowledge of using a questionnaire is positive, if answer alternatives are few and the questions could be explained verbally.

Clinical implications

ETUGT and MFRT tests are reliable tools to measure postural balance for young people with mild to moderate ID.

The low concurrent validity between different balance tests suggests that using several tests provides a fuller understanding of postural balance.

As young people with ID have reduced postural balance, muscle strength, and aerobic capacity, it seems important that they be given opportunities to train postural balance, muscle strength, and aerobic capacity.

Young people with ID, compared to young people without ID, do not rely more on their vision to maintain their postural balance, so special visual training for postural balance is unnecessary.

Young people with ID seem to adapt their postural responses slower than peers, which could lead to reduced postural balance. This limitation should be considered when planning posture balance training.

Because of the absence of associations between postural stability, level of physical activity, and physical capacity, these conditions should be evaluated and exercised separately.

Young people with ID might not be able to realize the health advantage of being physically active, as they do not seem to draw these conclusions. Therefore, it is important that they receive support from parents/guardians, school staff, physiotherapists, and others to encourage them to be more physically active.

Suggestions for further research

As the studies in this thesis had a cross-sectional design, longitudinal and controlled studies are needed to understand how postural balance develops and to understand what prevention measures are effective. People with severe and profound ID should also be investigated. It is important to further develop questionnaires that can be used by people with ID to access their health perception and physical activity in a reliable and valid way.

Conclusions

From the studies in this thesis, the following conclusions have been constructed about postural balance among young people with mild to moderate ID.

ETUGT and MFRT have good to excellent re-test reliability and a low value for absolute reliability, making these tests suitable for evaluating postural balance. OLS also has good relative and absolute reliability but has ceiling effects. The concurrent validity was low to none, findings that indicate that several balance tests are needed to determine a person's full postural balance ability.

Young people with mild to moderate ID have poorer postural balance and perform worse on muscle strength tests than age-matched peers. There were no strong correlations between muscle strength, height, BMI, and postural balance. Young people with ID do not rely more on vision to maintain postural balance than age-matched controls.

No differences were found in onset latency, use of strategies, muscle synergies, and time-to-peak amplitude after backward perturbations between young people with and without ID. Young people with ID reduced the time-to-peak amplitude in all muscles between the first and the sixth trial, but people without ID only reduced the time-to-peak amplitude in one muscle (i.e., the peak did not need to change). A pattern was seen that people with ID decreased their muscle response (IEMG) less than people without ID between first trial and sixth trial.

No associations between postural stability, physical activity, and physical capacity was found for young people. The answers from the health questionnaire did not agree with the results from the physical tests. It appears as if awareness of health is not associated with physical status.

Acknowledgements

This thesis was carried out at the Department of Community Medicine and Rehabilitation, division for Physiotherapy, Umeå University and The Swedish Development Centre for Handicap Sport in Bollnäs. I would like to express my sincerer gratitude to all people that have been involved in this work. I especially wish to thanks:

All the participants in the studies for the time and effort you have given and without you this thesis would never have appeared.

Börje Rehn, my supervisor for an excellent introduction into research and for sharing your great scientific knowledge. I especially appreciate your encouraging, fast and first-class constructive feedback and support. I have learnt a lot from you.

Anita Wester, my assistant supervisor for always being positive and supported. Your knowledge of intellectual disability has been a valuable value for this work and brought new angels into our discussions.

Gunnevi Sundelin, my assistant supervisor for believing in me when a came with the idée to my thesis and for sharing your great knowledge in research.

Lillemor Lundin-Olsson for sharing your knowledge of postural balance and your research advises.

Josefine Olsson, Louise Wallin, Elin Person and Hillevi Sundkvist my co-workers and co-authors in studies two and four.

Hans Stenlund and Leif Nilsson for excellent guiding and teaching in statistics.

Gunilla Frykberg and Britta Lindström for valuable advice with introductory chapter of the compilation thesis.

Colleges at the department of physiotherapy Umeå University. I appreciate all who have taken time and effort to read my work and taken part in seminars, which have given valuable feedback and lead the work forward. Special gratitude to PhD students that make me feel welcomed whenever I visit the department and Monica Edström for helping me with the layout and template of the thesis and Helena Grips that educated and guided me in to the world of EMG.

Colleges at Swedish Development Centre for Handicap Sports for believe in me and made it possible and a special thanks to Jenny Rosell for helping me with all kind of things.

The Royal Couples Wedding Fund that made it possible for me to start up this thesis.

Olé Olsen and all his crew for all of your support with the MuscleLab equipment.

Finally my family.

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