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A pilot study: investigating the physical activity pattern in children with cerebral palsy and typically developed children

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Abstract

Background: There's a concern that children today are too inactive, and technology makes it possible for children to reach out to their friends from the sofa, instead of standing up and walking out to meet them. Children with cerebral palsy (CP) experience motor disabilities and this may also impact their participation in daily activities. Since children change environment throughout their week, the activity patterns could possibly depend on whether it's during school time, leisure time during weekdays or weekends.

Aim: To apply the NTNU IDI software on one week Axivity sensor recordings from children with and without CP, to detect various activities, and provide feedback for further development of the study. Also, to investigate any differences in TD children between gender and age groups for time spent in sedentary, standing position and activity during school time, and leisure time during weekdays and weekend, as well as if the activity distribution is similar between CP and TD children, or as similarly depending on the time of the week.

Methods: 75 typically developed (TD) children between 7-15 years old, and 11 CP children (GMFCS level I-II) between 4-16 years old used an activity diary and wore two accelerometers (Axivity AX3) for 1 week, with the use of the NTNU IDI software algorithm, to measure activity patterns during school time, and leisure time in weekdays and weekends.

Results: During school time, secondary school TD children were significantly less active compared to primary school TD children, but during leisure time in weekdays and weekends, secondary school TD children were overall either similar or less in sedentary position compared to the primary school TD children. 7-9 years old TD boys show trends of higher overall activity compared to girls during school time and leisure time during weekdays, but not during the weekend, and there were no overall gender differences among 10-15 years old TD children. There were not found any significant differences in activity patterns between TD and CP children in neither school time, leisure time during weekdays or weekend.

Conclusion: For further development of the study, it was found that the activity diary entries from the participants of when they slept and woke up, were imprecise compared to the accelerometer data timeline, and not useful in the data analysis. Older TD children were overall less active during school time than younger TD children, while during weekends, the youngest TD children spent more time in sedentary position than the oldest TD children. The youngest boys showed certain trends of overall higher activity than the youngest girls, but among older TD children there were found no gender differences. There were not found any differences between CP and TD children's activity pattern.

Abstrakt

Bakgrunn: Det er en bekymring for at barn i dag er for inaktive, og teknologien gjør det mulig for barn å nå ut til vennene sine fra sofaen, i stedet for å gå ut for å møte dem. Barn med cerebral parese (CP) opplever motoriske funksjonshemminger, og som kan påvirke deres deltakelse i daglige aktiviteter. Siden barn endrer miljø gjennom uken, kan aktivitetsmønsteret muligens avhenge av om det er i skoletid, fritid på hverdager eller i helgene.

Mål: Å bruke NTNU IDI-programvaren på ukesmålinger av akselerometerdata, på barn med og uten CP, for å se på aktivitetsmønster, og gi tilbakemelding for videreutvikling av studien. Videre, for å undersøke eventuelle forskjeller mellom kjønn og aldersgrupper blant funksjonsfriske barn for tid brukt i stillesitting, stående og aktivitet i skoletid og fritid på hverdager og helger, samt om aktivitetsfordelingen er lik mellom CP og funksjonsfriske barn, eller varierer likt avhengig av tidspunktet for uken.

Metode: 75 funksjonsfriske barn mellom 7-15 år og 11 CP barn (GMFCS nivå I-II) mellom 4-16 år brukte en aktivitetsdagbok og hadde to akselerometerbrikker (Axivity AX3) på seg i 1 uke, med bruk av NTNU IDI software algoritmen, som verktøy i å måle aktivitetsmønstre i skoletid og fritid på hverdager og helger.

Resultat: I skoletid var funksjonfriske ungdomskolebarn signifikant mindre aktive sammenlignet med barneskolebarn, men i fritid på hverdager og helger var ungdomskolebarn generelt enten like eller mindre i stillesittende stilling i forhold til barneskolebarn. Funksjonsfriske 7-9 årige gutter viser trender av høyere samlet aktivitet sammenlignet med jevnaldrende jenter i skoletid og fritid på hverdager, bortsett fra helgene, og det var ingen generelle kjønnsforskjeller blant 10-15 år gamle funksjonsfriske barn. Det ble ikke funnet noen signifikante forskjeller i aktivitetsmønstre mellom funksjonsfriske barn og barn med CP hverken i skoletid, fritid på hverdager eller helg.

Konklusjon: For videre utvikling av studien ble det funnet at aktivitetsdagboksnotatene til deltakerne for når de la seg og våknet, var upresise sammenlignet med akselerometerdata-tidslinjen og ikke nyttig i dataanalysen. Eldre funksjonsfriske barn var generelt mindre aktive i skoletid enn de yngre, mens i helgene brukte de yngste funksjonsfriske barna mer tid i stillesitting enn de eldste barna. De yngste funksjonsfriske guttene viste visse tendenser med generelt høyere aktivitet enn de yngste jentene, men blant eldre funksjonsfriske barn ble det ikke funnet kjønnsforskjeller. Det ble ikke funnet noen forskjeller mellom barn med CP og funksjonsfriske barn sitt aktivitetsmønster.

Acknowledgements

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Abbreviations

CP = cerebral palsy

TD = typically developed

N = study population

GMFCS = Gross Motor Function Classification System

CI = confidence interval

PA = physical activity

Introduction

With technology moving forward, we live in a time where more children and adolescents have access to smartphones, tablets or PCs to easily communicate with friends or family in a matter of seconds, and without having to move an inch out of the sofa. In terms of sedentary behavior, numbers from the Norwegian directorate of health in 2012 shows that 15 years old children spend around 70% of their days in sedentary behavior compared to 60% among 9-year old's and around 50% among 6-year old's. Furthermore, their numbers show that 9 and 15 years old children spent 40 minutes more per day in sedentary behavior in 2011 compared their numbers from 2005/2006 (Kolle et al. 2012).

Physical activity (PA) is defined as any bodily movement that results in energy expenditure (Carspersen et al. 1985). Furthermore, reduced amounts of PA and increased amounts of sedentary behavior might be associated with chronic disease, overweight and disability (Ryan et al. 2015). The World's Health Organization says that among adolescents who were aged between 11-17 years, 81% of them were insufficiently physically active in 2010, as well as insufficient physical activity being one of the leading risk factors for death worldwide (WHO 2010). According to the Norwegian health directorate there's a clear drop in the amount of PA from 6 to 15 years of age, with activity levels among 6 years old children being 21% percent higher than 9-year old's, and the activity levels of 9-year old's being 40% higher than 15-year old's (Kolle et al. 2012). The same study also showed that in these age groups, there were also signs of boys having a higher level of physical activity compared to girls.

The activity patterns among children could possibly depend on what time of day it is, and if it's during school time, leisure time during weekdays or weekends. A study show that 9-10 years old children accumulated higher vigorous physical activity during non-school hours compared to during school, and more time was spent on sedentary behavior during weekends compared to weekdays (Steele et al. 2010).

Cerebral palsy (CP) is known as the most common cause of motor disabilities among children (Rosenbaum et al. 2006), and many children with CP have reduced cardiorespiratory endurance and muscle strength (Verschuren et al. 2016). CP is caused by a lesion on the brain before, during or shortly after birth (Rosenbaum et al. 2006). In terms of a functional view, CP children may have difficulties in performing purposeful and efficient physical bodily movements for several reasons, which can be spasticity, contractures, decreased balance, weakness, abnormal muscle coactivation, poor selective voluntary motor control, and

involuntary movement (Fowler et al. 2007). This could potentially work as a limitation when it comes to participation in daily activities that require higher physical intensity levels. However, when it comes to less physically demanding activities with friends or family, just being able to walk with them might be enough for them to choose to participate, and because of this, measuring their walking patterns could prove useful even if it's light physical activity.

Regarding measurements of activity patterns, accelerometers are frequently used to assess PA in children (Rowlands 2007). Accelerometers are small, lightweight monitors that can sample accelerations generated by body movements in one or more directions (Rowlands 2007). In terms of the feasibility of using accelerometers to measure activity on children with CP, a study show that accelerometers were successfully worn before, during, and directly after a constraint induced movement therapy program that lasted for 30 hours, to collect upper limb data among CP children, with a conclusion that the accelerometers could be worn even during high intensity (Coker-Bolt et al. 2017). Unlike the commonly used accelerometers like the ActiGraph GTX3 which uses its own Acti4 software, the Axivity AX3 accelerometers uses an open form of software, making it possible to create a new algorithm to calculate the outcome variables, and a study show that the NTNU IDI software algorithm used with the Axivity AX3 gives more accurate results compared to the Acti4 software when it comes to various common activity types (Ustad 2016). The Axivity AX3 sensors can record accelerations in 3 directions, and have built-in memory and a clock so it can record data for longer periods.

The eventual overall study aim is to determine the amount of time with different activities during school time, leisure time during weekdays and weekend in children with CP compared to TD**,** and specific aims of this pilot study were:

- To apply the recently developed software from NTNU IDI on one week Axivity sensor recordings from children with and without CP for the detection of different activities and give recommendations for further development.
- To investigate differences in TD children between age groups and gender for time spent in sedentary, standing position and activity during school time, and leisure time during weekdays and weekend.
- To investigate whether the activity distribution (time spent in sedentary, standing and active) in children with CP is similar and similarly dependent on time of the week (school time, leisure time during weekdays and weekend) as in TD children.

Methods

Participants and recruitment

The 75 TD children that were asked to participate, were all healthy without medical conditions or physical disabilities that might affect regular daily activities, between 7 and 15 years old and recruited from Lundamo school located in Sør-Trøndelag, Norway. The 11 CP children were recruited from different regions in Norway and were between 4-16 years old.

Equipment and protocol

Two accelerometers of the type Axivity sensor AX3 (Axivity, Newcastle, United Kingdom) were used per participant. The Axivity AX3 can record accelerations in 3 directions, and have built-in memory and a clock so it can record data for longer periods. The monitors were set to sample at a 100Hz frequency. The dimensions of the AX3 sensor are 23 x 32.5 x 7.6 mm, and they weigh 11 grams each.

The AX3 sensors were first wrapped in a finger cot with a toupee tape attached to the print side of the sensor. A 5x5 cm piece of Fixomull (BSN Medical) was then placed to the skin first, with the AX3 sensor then placed on top of this piece, and finally the sensor was covered by a water-resistant FlexiFit (Smith & Nephew). As shown in figure 1a and 1b, the Axivity AX3 sensors were placed on the right thigh (rectus femoris), and on the lower back (L3 vertebra) with the fabric print towards the skin and the USB connector pointing downwards.

The AX3 sensors and an activity diary were used for 1 week. The activity diary required the participant to fill out the form daily, which included when they went to sleep and woke up, as well as sick days and days home from school.

Figure 1a: Axivity AX3 attached on the right thigh (rectus femoris)

Figure 1b: Axivity AX3 attached on the lower back (L3 vertebra)

Accelerometer and activity diary analysis

The school schedule was available for the recruited TD children at Lundamo school, and the TD participants and parents wrote down in their diary when school started and finished each weekday during testing. Among the CP participants there was no detailed information about specific school hours, so every CP participant had their school hours set to 8.30-14.00 every weekday to match the average of the TD children school hours as much as possible. Most of the participants had reported diary entries that showed when they went to sleep and woke up, and this was shown on the accelerometer data timeline in Matlab to help get a better overview to judge when the participants went to sleep and woke up, together with the accelerometer readings in the timeline which showed when they stopped moving when going to bed and when they started to move when they woke up in the morning. In terms of marking when the participant went to bed and woke up, the accelerometer readings where always prioritized over diary entries to get the most accurate timestamp if these did not match.

The Axivity AX3 sensor software (Omgui) was used to transfer the raw accelerometer data from the AX3 sensors over to a PC. The collected raw accelerometer data was then sent to NTNU IDI and analyzed by them through their recently developed software designed for adolescents. The NTNU IDI software uses an algorithm to categorize the accelerometer activity into one out of its total 14 activity types, shown with a 1-second data window. The original 14 activity variables in the NTNU IDI software were:

1. Sitting
2. Standing
3. Walking
4. Shuffling
5. Stairs ascending/descending
6. Lying down
7. Sit cycling
8. Stand cycling
9. Running
10. Bending
11. Picking
12. Other vigorous activities
13. Unclassified
14. Undefined

For more detailed information regarding the NTNU IDI software, as well as the definitions they use for each activity variable, see the reference Ustad 2016.

The analysed accelerometer data which was sent back to us from NTNU IDI was then further processed with the Matlab software through a Matlab script, and a total of 9 variables out of the original 14 was used, and grouped into 3 different activity categories:

- Sedentary category: sitting and lying down
- Standing category: standing and shuffling
- Active category: walking, walking stairs ascending/descending, running, cycling sitting and cycling standing

Bending was also registered, but whenever the participant would bend, it would register as the activity type they did 1 second earlier (for example if they walked for 10 seconds, then stopped to bend quickly for 2 seconds, and then walked again for 10 more seconds it would be registered as 22 seconds of continuous walking).

The amount of time spent in these 3 different activity categories was then investigated through the Matlab script, as well as the percentage amount of awake time spent in these categories. The accelerometer data was reviewed as a timeline in Matlab on each participant to look for missing data, and check for strange readings in case there had been problems with the accelerometer sensors.

As an exclusion criteria for the data material used in results, each participant needed to have a minimum of 3 out of 5 weekdays with complete data, and complete data for both Saturday and Sunday during the weekend.

Statistical analysis

The statistical analysis was done with SPSS version 24 (SPSS, Inc., Chicago, IL), and descriptive analyses, histograms, one-way ANOVA statistical tests and Tukey post-hoc tests were used.

The significance threshold was set at 0.05 in the one-way ANOVA and Tukey post-hoc test, and the data material on all the variables seemed normally distributed after running it through histograms. Due to a low number of CP participants, as well as relatively low numbers in different TD age and gender groups, results that showed p-values < 0.1 was also highlighted in case of trends.

Results

Participants

Table 1. Participant chart

	TD	CP
N (male/female)	75 (39/36)	11 (6/5)
Missing accelerometer data	19	0
Incomplete data	8	3
Below 6 years old (kindergarten)	0	2
N after exclusion (male/female)	48 (21/27)	6 (5/1)

Table 1 show that among the 75 TD participants, 19 had missing accelerometer data, and 8 had incomplete data which could not be used. Among the 11 CP participants, 3 had incomplete data, and 2 were still in kindergarten (both were 4 years old) and were excluded.

Table 2. Participant data chart

	TD	CP
N (male/female)	48 (21/27)	6 (5/1)
Age (years)	7 – 15 (10 mean)	6 – 16 (10 mean)
Height (cm)	117 – 176 (149 mean)	118 – 164 (135 mean)
Weight (kg)	22 – 65 (41 mean)	19 – 43 (31 mean)
GMFCS		5 participants with GMFCS-1, 1 participant with GMFCS-2.

Table 2 show the descriptive characteristics of the remaining TD and CP participants after exclusion.

TD children awake time

In figure 2, the Tukey post-hoc test show that 7-9 years old children had significantly less awake time during weekdays compared to both the 10-12 group ($p < 0.001$) and the 13-15 group ($p < 0.001$), while the 10-12 group had significantly less awake time compared to the 13-15 group ($p = 0.021$). During weekends, there was no significant difference between the 7-9, 10-12 and 13-15 age groups ($p = 0.740$).

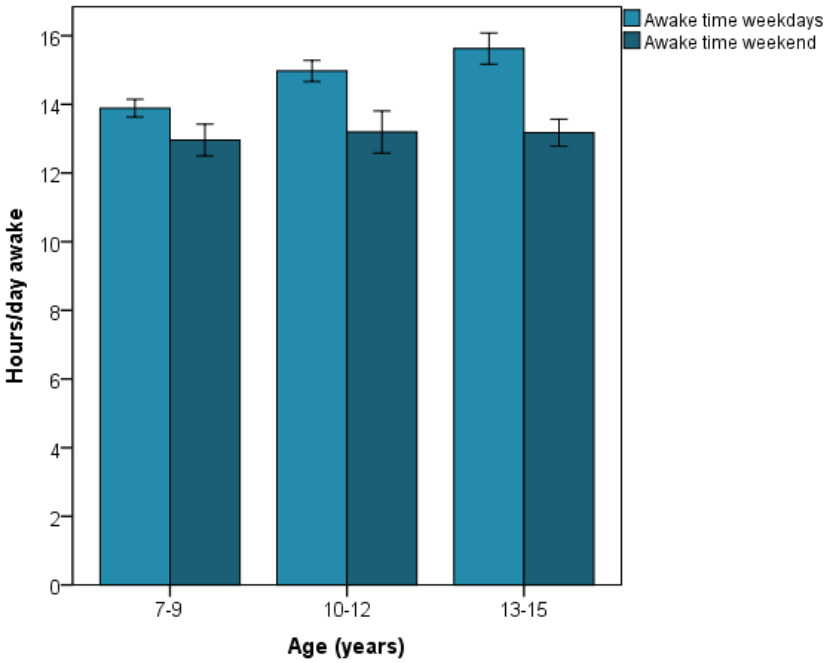

Figure 2: awake time during weekdays and weekend among groups of 7-9, 10-12 and 13-15 years old TD children. Error bars indicate 95% CI.

TD children during school time

Figure 3 show that there was a significant difference between the three age groups in sedentary ($p = 0.018$) and active ($p < 0.001$), but not in standing ($p = 0.71$). The Tukey post-hoc test shows that the 13-15 years old children spend significantly more time in sedentary compared to the 10-12 group ($p = 0.016$) but not compared to the 7-9 group ($p = 0.061$). The Tukey post-hoc also shows that the 13-15 years old children spend significantly less time in active position compared to both the 7-9 group ($p < 0.001$) and the 10-12 group ($p < 0.001$).

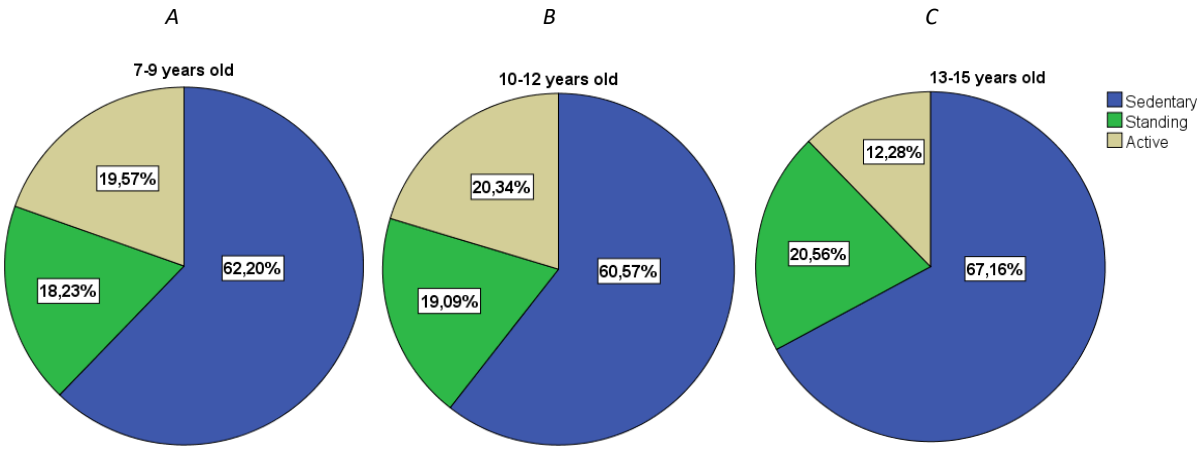

Figure 3: activity during school time with the percentage amount in sedentary, standing and active category among groups of 7-9 years old (A), 10-12 years old (B) and 13-15 years old (C) TD children.

During school time, TD children were in sedentary position between 3 to 3.5 hours (figure 4A), in standing position between 50 to 75 minutes (figure 4B) and in active position between 40 to 70 minutes (figure 4C). There were found no statistical differences between genders during school time in any of the three age groups, in neither the sedentary category (figure 4A, with lowest p = 0.109) or in the standing category (figure 4B, with lowest p = 0.175). However, figure 4C show that the 7-9 years old boys were significantly more active during school time compared to 7-9 years old girls (p = 0.005), but there were found no statistical differences between genders in the active category in the other two age groups (lowest p = 0.335).

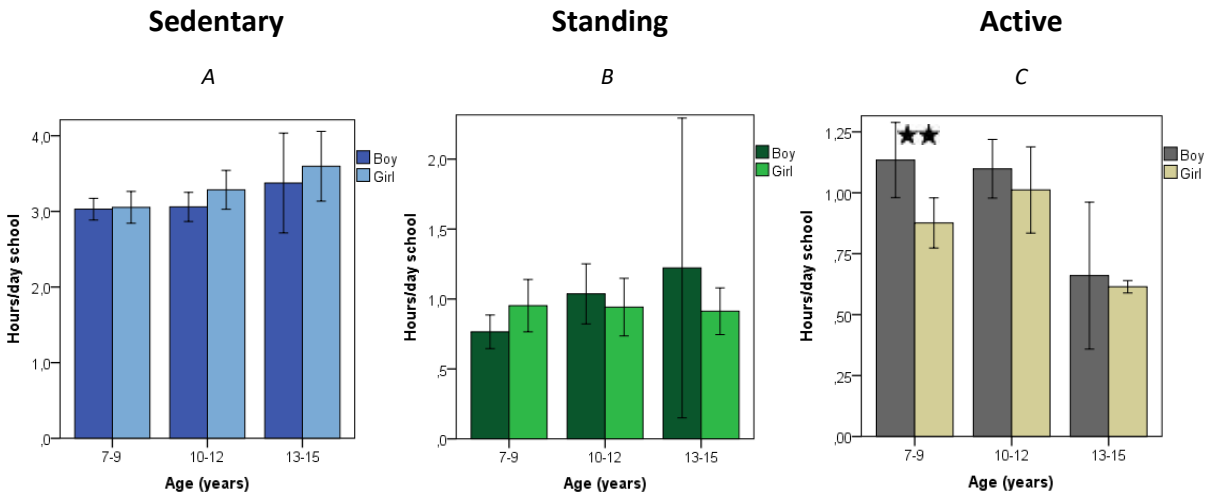

Figure 4: activity during school time with the amount of time (hours) in sedentary (A), standing (B) and active (C) category among groups of 7-9 years old, 10-12 years old, and 13-15 years old TD boys and girls. Two stars symbol indicates p-value < 0.05 in difference between genders. Error bars indicate 95% CI.

TD children during leisure time in weekdays

Figure 5 show there was a significant difference between the three age groups in standing (p = 0.013), but not in sedentary (p = 0.066) or active (p = 0.152). The Tukey post-hoc test shows that the 13-15 years old children spend significantly more time in standing compared to both the 7-9 group (p = 0.020) and the 10-12 group (p = 0.019). The Tukey post-hoc test shows no difference in standing between the 7-9 and 10-12 group (p = 0.97).

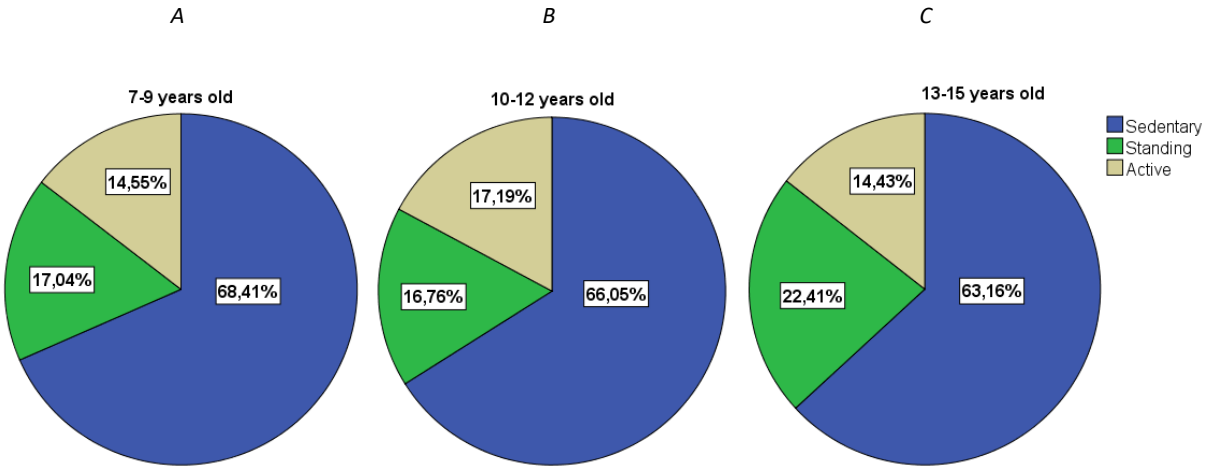

Figure 5: activity during leisure time in weekdays with the percentage amount in sedentary, standing and active category among groups of 7-9 years old (A), 10-12 years old (B) and 13-15 years old (C) TD children.

During leisure time in weekdays, TD children were in sedentary position between 6 to 6.5 hours (figure 6A), in standing position between 75 to 225 minutes (figure 6B) and in active position between 75 to 100 minutes (figure 6C). There were found no statistical differences between genders during school time in any of the three age groups, in neither the sedentary category (figure 6A, lowest p = 0.281) or in the active category (figure 6C, lowest p = 0.054). However, figure 6B show that 7-9 years old girls spend significantly more time in standing position compared to 7-9 years old boys (p = 0.012), but there were found no statistical differences between genders in the standing category in the other two age groups (lowest p = 0.56).

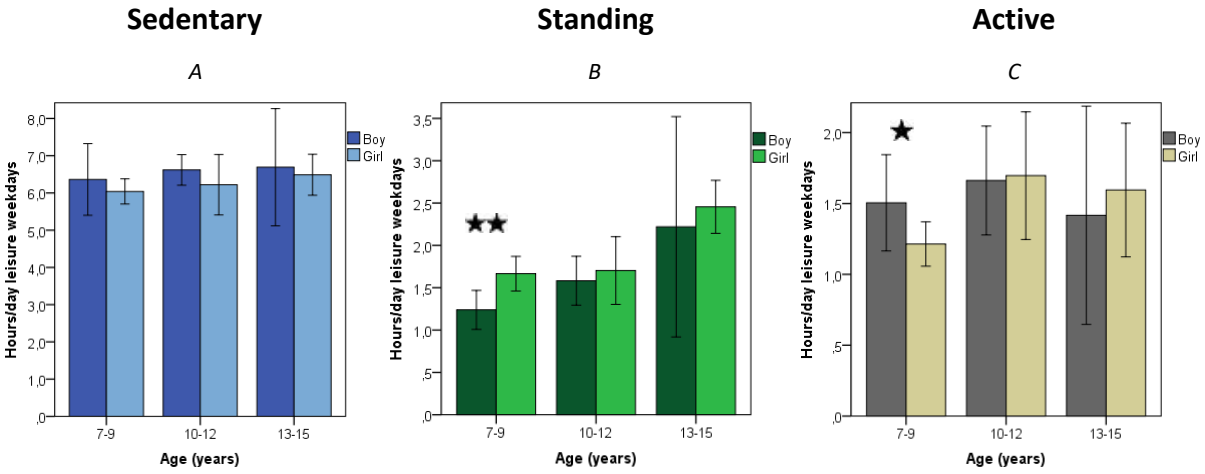

Figure 6: activity during leisure time in weekdays with the amount of time (hours) in sedentary (A), standing (B) and active (C) category among groups of 7-9 years old, 10-12 years old, and 13-15 years old TD boys and girls. One star symbol indicates p-value < 0.1, and two stars indicate p-value < 0.05 in difference between genders. Error bars indicate 95% CI.

TD children during leisure time in weekends

Figure 7 show that there was a significant difference between the three age groups in sedentary (p = 0.018) and standing (p = 0.002), but not in active (p = 0.088). The Tukey post-hoc test shows that the 13-15 group spend significantly less time in sedentary position compared to the 7-9 group (p = 0.013) but not compared to the 10-12 group (p = 0.11). The Tukey post-hoc test also shows that the 13-15 group spend significantly more time in standing position compared to both the 7-9 group (p = 0.003) and the 10-12 group (p = 0.003).

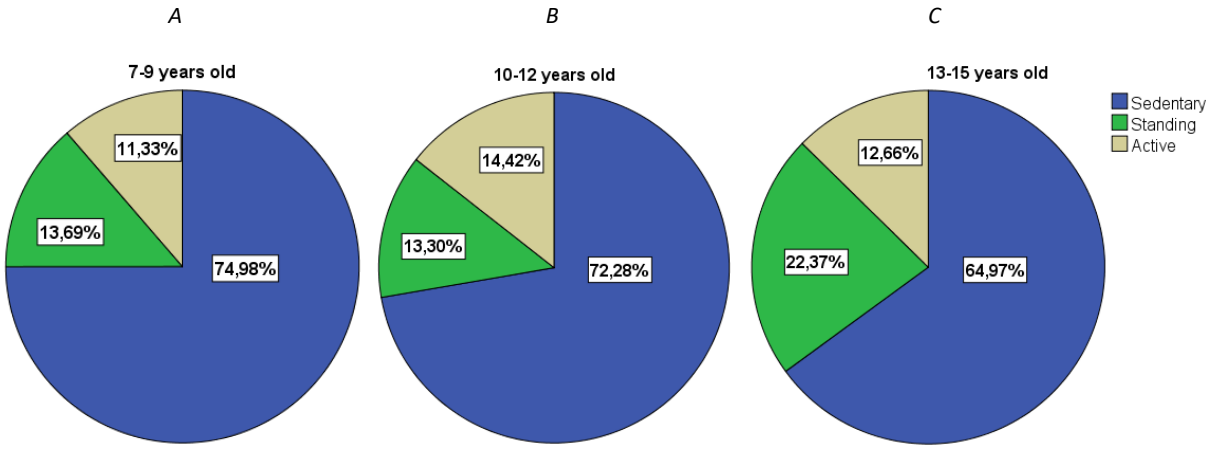

Figure 7: activity during leisure time in weekends with the percentage amount in sedentary, standing and active category among groups of 7-9 years old (A), 10-12 years old (B) and 13-15 years old (C) TD children.

During leisure time in weekends, TD children were in sedentary position between 8.3 to 10.6 hours (figure 8A), in standing position between 1.3 to 3.1 hours (figure 8B) and in active position between 85 to 115 minutes (figure 8C). In the sedentary position (figure 8A), 7-9 years old boys spend significantly more time compared to 7-9 years old girls ($p = 0.046$), but there was found no statistical differences between genders in the sedentary category in the other two age groups (lowest $p = 7.55$). In the standing position (figure 8B), 7-9 years old girls spend significantly more time compared to 7-9 years old boys ($p = 0.015$), but there was found no statistical differences between genders in the standing category in the other two age groups (lowest $p = 0.627$). In the active category (figure 8C) there was found no statistical differences between among the three age groups (lowest $p = 0.584$).

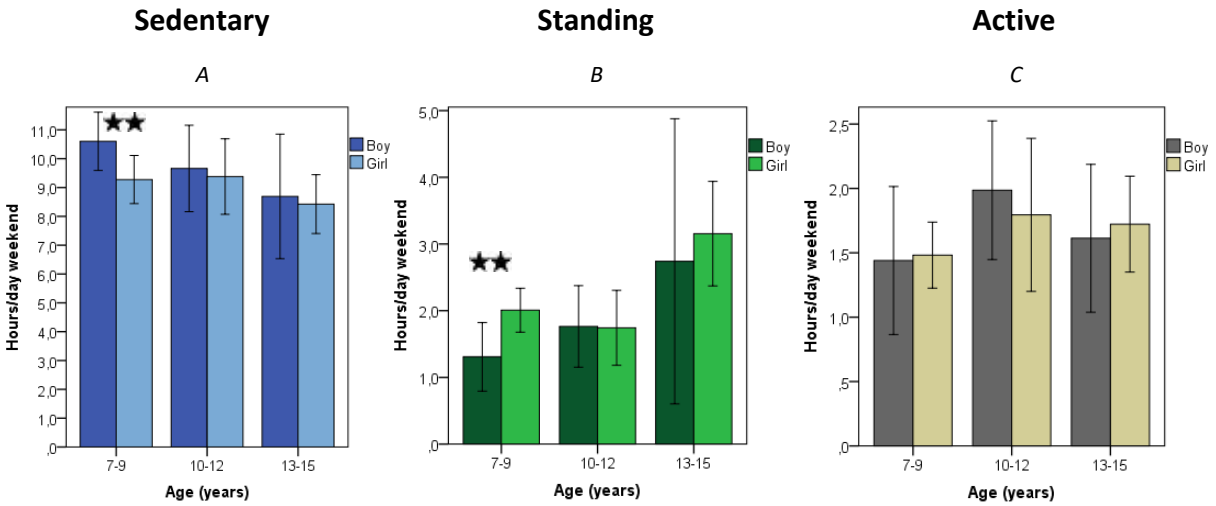

Figure 8: activity during leisure time in weekends with the amount of time (hours) in sedentary (A), standing (B) and active (C) category among groups of 7-9 years old, 10-12 years old, and 13-15 years old TD boys and girls. Two stars symbol indicate p-value < 0.05 in difference between genders. Error bars indicate 95% CI.

TD children compared to CP children during school time

Figure 9 show that during school time, there was not found any significant differences between the TD group (7-15 years) and the CP group (6-16 years) in neither sedentary (p = 0.070), standing (p = 0.66) or active (p = 0.072).

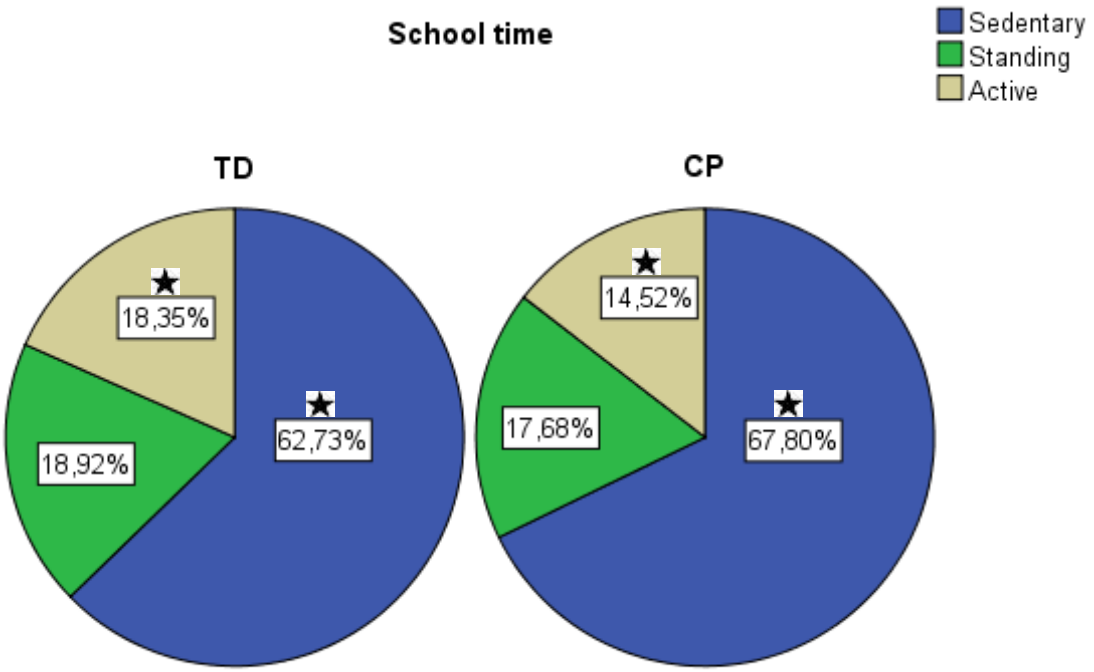

Figure 9: Activity during school time, with the percentage amount of activity in sedentary, standing, and active category among 48 TD children (7-15 years old) compared to 6 CP children (6-16 years old). One star symbol indicates p < 0.1 in difference between TD and CP.

TD children compared to CP children during leisure time in weekdays

Figure 10 show that there was not found any significant differences between the TD group (7-15 years) and the CP group (6-16 years), in neither sedentary (p = 0.55), standing (p = 0.53) or active (p = 0.87).

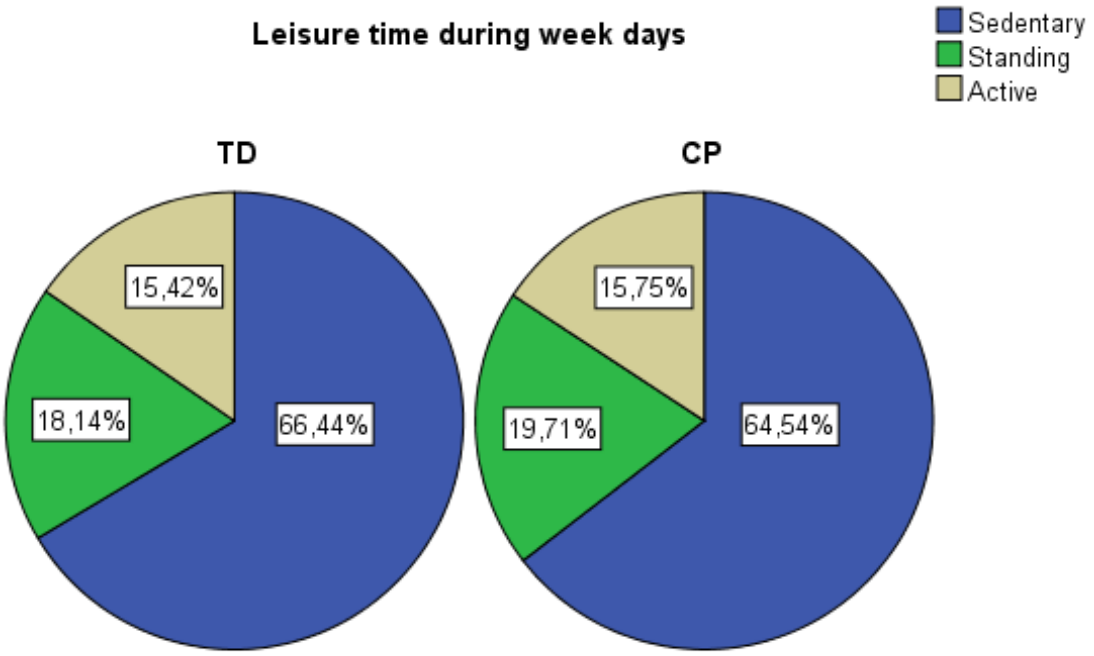

Figure 10: Activity during leisure time in weekdays, with the percentage amount of activity in sedentary, standing, and active category among 48 TD children (7-15 years old) compared to 6 CP children (6-16 years old)

TD children compared to CP children during leisure time in weekends

Figure 11 show that there was not found any significant differences between the TD group (7-15 years) and the CP group (6-16 years) in neither sedentary (p = 0.55), standing (p = 0.51) or active (p = 0.79).

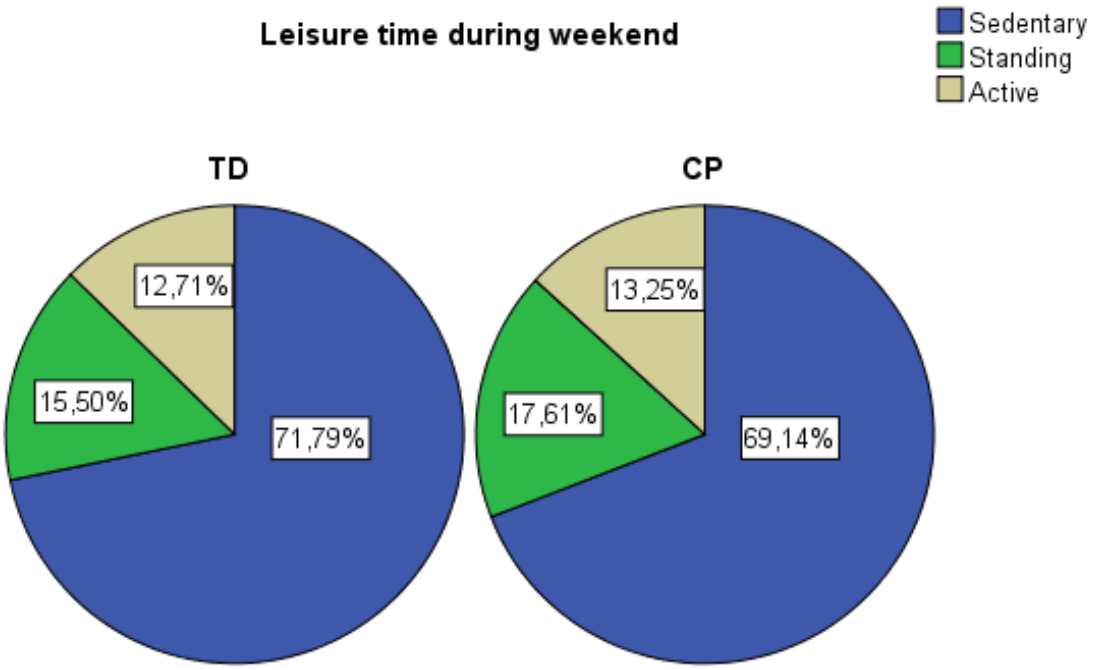

Figure 11: Activity during leisure time in weekends, with the percentage amount of activity in sedentary, standing, and active category among 48 TD children (7-15 years old) compared to 6 CP children (6-16 years old)

Discussion

One of the aims of this pilot study was to apply the developed NTNU IDI software on one week Axivity sensor recordings from children with and without CP to detect different activities, and provide feedback for further development of the study. The main findings related to this, show that the activity diary entries of the time when they went to sleep and woke up, were often inaccurate compared to the accelerometer data timeline, and therefore not useful in the data analysis.

The study aims also consisted of investigating differences in TD children between gender and age groups, in terms of time spent in sedentary, standing and active position during school time, and leisure time in weekdays and weekend. The findings here were that in the 7-9 years age group, boys spent significantly more time in active position during school time compared to girls, boys spent more time than girls in sedentary behavior in leisure time during weekends, while girls spent more time than boys in standing position during both leisure time in weekdays and weekends. There were found no significant gender differences in neither the 10-12 years or 13-15 years old TD groups. Furthermore, in terms of age differences, findings show that during school time 13-15 years old TD children had a significantly lower percentage of their time in active behavior compared to both 7-9 and 10-12 years old TD children, as well as a higher percentage of their time in sedentary position compared to the 10-12 group, but not the 7-9 group. There were found no significant differences between the 7-9 and 10-12 years TD groups during school. During leisure time in weekdays, there were found no significant differences between the three age groups except that the 13-15 years TD group had a higher percentage of standing position compared to both the 7-9 and 10-12 years TD group. During weekends, the same was found in standing behavior, where the 13-15 years TD group had a significantly higher percentage of time in standing compared to both the 7-9 and 10-12 years TD groups, and the 13-15 group also had a lower percentage in sedentary position compared to the 7-9 group. There were not found any age differences in active behavior during leisure time in weekends.

The third study aim was to investigate if the activity distribution in terms of time spent in sedentary, standing and active position were similar between CP and TD children, as well as similarly depending on the time of the week (school time, and leisure time during weekdays and weekend). Here there were not found any significant differences between TD and CP children, although there were few CP children (n=6) compared to TD children (n=48).

Recommendations for further development

Some of the potential data had to be excluded because of either missing data or incomplete accelerometer data due to either the children scratching or fiddling with the sensors, or the sensors loosening and falling off by themselves. For the future, and for CP children participants especially where recruitment can prove to be difficult, it might be considered to improve the methods used for attaching the accelerometer sensors to the body more securely, so that perhaps a higher percentage of the collected data might be usable later.

In terms of the activity diary, it is questionable how necessary their sleep and wake up entries are, as the accelerometer readings were often slightly or very different. As an example, the activity diary entry could state "went to bed 20.00", while the accelerometer readings showed that they were active for over an hour more. This could also be the case if the parents filled out the activity diaries for them in the belief that their children were obeying the sleep routine instead of perhaps staying awake longer. Due to this, the sleep and wake up entries in the activity diary were not found to be useful for the data analysis, since the accelerometer data timelines looked more precise and were always prioritized when marking the time stamps.

Since there was no detailed information of specific school hours in the CP activity diary logs, the school hours for all the CP participants were set from 8.30 to 14.00 to match the similar school hour average among the TD children. Regarding future data collection, it might be considered to include detailed school hours in the future for both CP and TD participants. However, it could also be questioned if it would have an impact on the results or not.

The walking variable was included in the active category, mainly because walking might give an indication on how much CP children participate in daily activities. However, walking is not necessarily a very demanding physical activity, depending on the characteristics of the participant. For the future development of the study, it might be considered to separate walking and high intensity variables into two different activity categories, to specifically see how much time children spend in high intensity activities as well.

The Lundamo school where the TD participants were recruited from, offers a wide variety of outdoor activities, such as a basket court, football field, slides, skating/BMX ramp, running track et cetera, so there did not seem to be any noticeable limiting factors in terms of the options the children here have when it comes to being active outdoors during their recess at school, or in their leisure time if they live nearby the school. Several of the TD children participants from Lundamo school might share friends, and it can be questioned if all the

participants coming from the same school and environment could have an impact on their mutual interests which may affect their daily activity pattern as well. A suggestion for the future development would be to recruit TD children from different schools and environment, and in terms of recruitment of the CP participants it could be considered to also recruit a gender and age matched TD child from the same school as the CP child if possible.

TD children

When interpreting the results of this study regarding time (hours) spent among the TD children, it is useful to look at their amount of awake time first. During weekdays, the awake time is different between the TD age groups, and this affects how much time that is "available" to be spent in the activity categories. Younger TD children at the age of 7-9 have nearly 14 hours of awake time, 10-12 years old TD children have 15 hours awake time, while the 13-15 years old age group have almost 16 hours awake time, during weekdays. The awake time is around 13 hours for all the three age groups during weekends however.

During school time, the results of this study show that the 7-9 years old TD boys spent significantly more time in active behavior compared to girls, with 15 minutes more per school day which adds up to 75 minutes more time spent in active behavior through the week. The results also show that 13-15 years old TD children spend 67% of their school time in sedentary behavior, compared to 60% among the 10-12 years TD group. Further, the findings show that 13-15 years old children who were in secondary school, spend 12% of their school time in active behavior, compared to 20% among the 7-9 and 10-12 years old TD children who were still in primary school.

During leisure time in weekdays, 7-9 years old TD girls spent significantly more time (15 minutes more) in standing position compared to 7-9 years old TD boys, and 7-9 years old boys spent 15 minutes more in active behavior compared to girls, but there was not found a statistical significant gender difference in terms of the active behavior ($p = 0.054$). The 13-15 years old TD children spent 22% in standing position compared to around 17% among the other two age groups, but otherwise all the three age groups (7-9, 10-12, 13-15 years) were quite similar in leisure time during weekdays.

During leisure time in weekends, 7-9 years old TD boys spent 70 minutes more in sedentary position, and 40 minutes less in standing position compared to 7-9 years old TD girls.

Furthermore, the 7-9 years old TD group spent 75%, the 10-12 years old TD group spent 72% and the 13-15 years old TD group spent 65% of their awake time in sedentary position during the weekends. The 7-9 and the 10-12 years old TD groups spent around 13-14% of their awake time in standing position, while the 13-15 years old TD group spent 22%. Lastly, TD children between 7-15 years of age spent only 11-14% of their awake time in active behavior during the weekend.

TD children are in sedentary position in more than 60% of their awake time, independent of age, gender and situation. Interestingly, older secondary school TD children (13-15 years old) were significantly less active compared to primary school TD children (7-12 years old) specifically during school time, but when it comes to leisure time during both weekdays and weekend, the trend changes and secondary school TD children were overall either similar or less sedentary compared to the primary school children. In terms of during leisure time in weekdays and weekend, this differentiates the trends compared to the numbers from the Norwegian directorate of health in 2012 (Kolle et al. 2012), which show that the older children (15 years old) spend more time in sedentary behavior and less time active compared to 6 and 9-year-olds. However, during school hours, the trends are similar. In terms of age differences, the same can be said compared to a different study that measured sedentary behavior and physical activity with accelerometers among 7-14 years old children, which found that younger children were overall more active than older children, and that boys were overall more physically active compared to girls during awake hours (Husu et al. 2016). In comparison to that study, in the 7-9 years old TD group, boys show similar trends of higher overall activity compared to girls during school time and leisure time during weekdays, however there are no overall gender differences in the 10-12 years or 13-15 years group. Another study also found that 12-14 years old children had lower sedentary time and greater moderate-to-vigorous activity compared to 15-17 years old (Kim et al. 2017), which again share the similar trends in age differences as the previous studies mentioned.

It can be questioned how the society can try to improve the trends in terms of unhealthy activity patterns and excessive amounts of sedentary behavior, although there has been some success from using interventions designed to increase physical activity and/or reduce sedentary behavior in children (Taverno et al. 2016).

TD children compared to CP children

There were found no significant differences in activity patterns between the TD group and the CP group in neither school time, leisure during weekdays or during the weekend. However, the CP population was small (n=6) compared to the TD population (n=48), and there were trends ($p < 0.1$) that showed a lower percentage of the active category among CP children compared to TD children during school time, as well as trends ($p < 0.1$) showing a higher percentage of sedentary behavior among CP children compared to TD children during school time.

GMFCS (Gross Motor Functional Classification System), is a description of the mobility function in terms of the activities and participation levels of the International Classification of Functioning (ICF) that is commonly used for persons with CP, where GMFCS level 1 is considered without restrictions, level 2 is considered with restrictions, and level 3 considered with the need of assistive devices (Fowler et al. 2007). According to a cross-sectional study (Ryan et al. 2015) that had 33 CP participants aged between 6-10 and a GMFCS that varied from level 1-3, with 33 TD children with matching age and gender, their study showed that CP children spent more time in sedentary behavior, and less time in moderate-to-vigorous activity compared to their TD group. It is worth to note that the results in this study have only 6 CP participants compared to the Ryan et al. study, where 5 have GMFCS level 1 and only one has GMFCS level 2, while the GMFCS levels were between level 1 and 3 in the Ryan et al. study. In terms of disability, the difference between GMFCS level 1 and level 3 is significant, and this could potentially explain the difference in results, along with the large difference in CP population between the two studies. Lastly, moderate-to-vigorous activity does not necessarily compare itself directly with active behavior where walking is included as one of the active variables.

Strengths and limitations

This study investigates school time, leisure in weekdays and leisure in weekends separately, since children may choose to have different activity patterns depending on these 3 scenarios. Further, the use of two Axivity AX3 accelerometers per participant to measure their activity pattern, combined with the NTNU IDI software, makes it possible to collect a detailed overview of their activity patterns.

The number of TD participants with data material in the 13-15 years old group (N=10) is lower compared to the 10-12 years group (N=16) and the 7-9 years group (N=22), and this could have an impact on the results when looking at age differences. The number of CP participants in the results are quite low (N=6), and thus makes it difficult to compare them equally with the TD children (N=48). The age differences between the TD group and CP group are slightly different, where the participating TD children varies from 7-15 years old with a mean age of 10 years, whereas the CP group varies from 6-16 years old, but with the same mean age of 10 years. Lastly, the population of each gender group in the TD results is quite low, and this may have an impact on the results as well.

Conclusion

In terms of further development of the study, it was found that the activity diary entries of sleeping and waking up were imprecise compared to the accelerometer data timeline, and not found to be useful in the data analysis. During school time, secondary school TD children (13-15 years old) were significantly less active compared to primary school TD children (7-12 years old), but when it comes to leisure time during both weekdays and weekend, secondary school TD children (13-15 years) were overall either similar or less in sedentary position compared to the primary school TD children (7-12 years). Furthermore, 7-9 years old TD boys show trends of higher overall activity compared to girls during school time and leisure time during weekdays, but not during the weekend, and there were no overall gender differences among 10-15 years old TD children. There were not found any significant differences in activity patterns between TD and CP children in neither school time, leisure time during weekdays or weekend.

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