

Original Research

## A Participation-Focused Exercise Intervention for Children with Neurodevelopmental Disorders: Feasibility, Acceptability, and Impact on Sleep and Wellbeing

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### Abstract

Sleep-related difficulties are common in children with neurodevelopmental disabilities. Poor sleep health is associated with detrimental impacts not only for the child/young person, but also their family members. Exercise is considered to be important for sleep health, improving duration and quality of sleep in adult studies, however there is limited literature on impact in children with neurodevelopmental disabilities, and barriers to participation exist for this group. We set out to test the feasibility and acceptability of an exercise-intervention for children with neurodevelopmental disorders and troublesome sleep, whilst also evaluating impact on child's sleep and whole family wellbeing. Design: Feasibility study. Setting: Community-based Sleep Clinic for children with neurodevelopmental disorders. Patients: Total 15 children aged 5 years 0 months to 15 years 11 months. Intervention: A 10-week exercise intervention, providing one swimming session, and one dry-sports session (1.5 hours per session) per week (overall 20 x 1.5 hours). Main outcome measures: Mixed-methods design; primary outcomes of feasibility and acceptability measured by ability to run intervention, attrition rate, and semi-structured parent-completed questionnaire of



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acceptability, appropriateness, and free-text comments. Secondary outcomes of impact on sleep and wellbeing measured by pre-and post-intervention parent-reported diary of child's sleep (14-nights) and semi-structured parent-reported Likert-scale questionnaire for impact on child's sleep, wellbeing, mood and behaviour, and family wellbeing. Descriptive analyses applied to the generated data. Primary outcomes: Twelve of 15 recruited participants took part on a regular basis; attendance rate remained high throughout the 10 weeks at swimming sessions, but was lower at dry-sports sessions. Parent-reported Likert-scale measures found the intervention to be acceptable to families and appropriate to their child's needs. All attending families were interested in future sessions if these were to be offered. Secondary outcomes: Average parent-reported sleep-onset latency, night-wakings, and estimated overall sleep duration of child improved over the course of the intervention. Families' perceived impact on child and family wellbeing was overwhelmingly positive. Provision of a participation-focused exercise intervention for children with neurodevelopmental disorders in our area has been possible, and has been well-received by families. Families reported positive impacts on child's sleep, wellbeing, and family wellbeing over the course of the intervention. Perceived barriers to completing the intervention included competing family priorities, family stressors, language barriers, and transport barriers. Overcoming such barriers to participation in physical activity for children with neurodevelopmental disorders continues to be important.

### **Keywords**

Sleep; exercise; participation; child disability

## **1. Introduction**

It has long been established that sleep is imperative for human functioning; inadequate sleep is associated with detrimental impacts on multiple body systems and functions, including immunity, cell restoration, growth, appetite regulation, learning, memory, executive functioning, and mental wellbeing [1, 2].

Recommended sleep duration for children varies with age, with current guidance suggesting typically developing 6-12 year-old children aim for 9-12 hours of sleep per night [3]. It is, however, widely accepted that sleep patterns in children with neurodevelopmental disabilities can vary considerably from this [4]. Sleep-related disturbances are reported in up to 86% of children with autism spectrum conditions, 44-86% of children with intellectual disabilities, and 70% of children with Attention Deficit Hyperactivity Disorders (ADHD) [5, 6]. The range of sleep-related disorders in this group is extensive, including behavioural insomnias of childhood, fragmented sleep patterns, circadian rhythm disorders, and higher risk of sleep-disordered breathing in some groups (e.g. Down Syndrome). Co-existing mental health disorders, maladaptive behavioural patterns, and physical and neurodevelopmental comorbidities contribute to the complex interplay of factors culminating in a higher risk of disrupted sleep patterns [7].

Sleep disturbance in children impacts on sleep opportunity for parents, with an extensive evidence base suggesting sleep deprivation in parents impacts their ability to cope with the challenges of raising a child with complex disability [8, 9].

It is widely recommended that engaging in adequate physical activity can support healthy sleep patterns, however the relationship between exercise/sedentary activity and sleep in children is continuing to be explored in the literature [10-16]. Physical activity has been shown to improve sleep-onset and sleep efficiency (proportion of time in bed spent sleeping) [12, 13], and increase total sleep duration [14] in *typically developing* children. Positive relationships between physical activity, sleep, and psychological functioning have been described in adolescents [15]; Kalak et al [16] found introduction of a 30-minute morning run for 3 weeks in typically developing adolescents (N = 51) led to increased slow-wave sleep, reduction in sleep-onset latency (SOL; time taken to fall asleep), and improved mood and concentration for those randomised to the intervention group.

The impact of exercise on sleep in children *with developmental disabilities* is so far tentative. Small-scale studies suggest physical activity improves sleep quality [17-20]; Wachob et al. [19] documented objective sleep and physical activity measures using accelerometer devices in 10 children with autism spectrum disorder over the course of 7-days, finding correlations between higher levels of physical activity and improved sleep patterns. Brand's pilot study [20] of aerobic exercise (involving 30 minute bicycle work-out) and motor skills training (primarily throwing and catching a ball, and balance training using a beam) in 10 children with Autism Spectrum Disorders found 60 minutes of activity three times a week for 3 weeks led to better sleep efficiency and shorter sleep-onset latency using objective measures (sleep-EEG), and improved morning mood measured through parent-reported Likert scale. Recommendations included that future studies should assess the benefit of a longer intervention period, and impact on the wider family.

The World Health Organisation [21] recommend children aged 5-17 years aim for 60 minutes of moderate-to vigorous-intensity activity daily (mostly aerobic), and with vigorous-intensity at least 3 times per week. The recommendation for children with disabilities is that these recommendations should be followed "*whenever possible*".

Barriers to engaging in physical activity for children with neurodevelopmental disabilities are potentially wide-ranging, including opportunity and access to activities that meet needs, accessibility of venues and transport options, family resources to support attendance at activities (both tangible, such as available transport and finances, and non-tangible, such as parental time and energy), and cost of provision of safe activities that are likely to require a higher staff-to-child ratio than for typically developing children.

Our local experience stems from an evaluation of sleep-related problems in children attending two special-needs schools in our area in South London [22], which found parent-reported sleep difficulties in the index child to be highly prevalent, and equally common at both primary and secondary school age (59% and 61% respectively). A local community-based sleep clinic for children with neurodevelopmental disorders and/or severe psychosocial adversity was established in response to this identified gap in service, and has been running for over 3 years, receiving over 600 referrals to date.

Pathway through the service includes a detailed Paediatrician-led assessment, with identification of likely contributing factors to sleep-related difficulties, and generation of potential solutions. One commonly identified factor is lack of opportunity or access to appropriate physical activities for

children with developmental disabilities, with many children spending hours engaged in screen-based activities as an alternative occupation.

The current study was therefore designed to explore whether an exercise-intervention developed to meet the needs of children within our local sleep clinic population could be feasibly implemented (to meet an identified gap in opportunity and availability in the local area), and if so, to explore the views of families attending, whilst also addressing the need for further research in this area, evaluation of a longer intervention period, and impact on the wider family, as raised by previous researchers.

With this in mind, our primary research questions were: Is delivery of an exercise intervention for children with developmental disabilities in our local area feasible? And if so, do parents find the intervention acceptable?

Secondary questions of interest were: Does the intervention improve the reported sleep pattern of the child? And do parents report changes to wellbeing and functioning following the intervention?

A grant of £ 6,500 was available to support the delivery of a project to address these questions.

## **2. Materials and Methods**

### **2.1 Intervention**

The exercise intervention was designed and provided by a local team of sports instructors, specifically trained in supporting children with additional needs (London PE and Schools Sports Network). This comprised one session of swimming per week (1.5 hours) at a local swimming pool within a sheltered housing development (pool-use solely for the participants and intervention team during the allocated sessions), and one session of dry-sports (trampolining, balls, scooters, and use of a nature-walk) per week (1.5 hours) at a local community sports development within a school-setting, for 10 weeks between April and June 2019. Sessions were delivered in the after-school period. Ratio of instructors to children was 1:2, with 8 instructors (including the team lead) supporting 15 children, ensuring adequate staffing to engage, facilitate participation, and maintain safety of all children. Children were encouraged to engage in a range of activities during the sessions, with turn-taking of the trampoline equipment and at times being led by the child's interest/motivation for specific activities. The aim was to achieve physical exertion (unspecified intensity) for all children throughout the sessions.

### **2.2 Participants**

Funding allowed for 15 participants. Inclusion criteria were: child under the care of Evelina London Community Paediatric Sleep Clinic, with neurodevelopmental difficulties/disability (may have neurodevelopmental or neurodisability diagnosis, or be under assessment within neurodevelopmental service), and age range 5 years 0 months, to 15 years 11 months and 30 days.

Exclusion criteria were high-risk safeguarding concerns (e.g. child in process of being placed in Local Authority foster care), and health issues that may impact on safe participation (e.g. awaiting investigations for suspected epilepsy or potential cardiac disorder).

### 2.3 Outcome Measures

A mixed-methods approach was taken to explore the primary research questions: the feasibility of such an intervention within our local boroughs was tested by the ability to set-up, run, and complete delivery of the intervention within the available funding. Acceptability of the intervention was measured through semi-structured (Likert-scale and free-text) parent-reported questionnaire at the end of intervention, and through attrition rate.

Further data was gathered to explore secondary questions of interest as below:

Perceived impact on child's sleep pattern measured through parent-completed sleep diaries (Figure 1) for 2 weeks (14 nights) prior to the start of the intervention, and for the last 2 weeks (14 nights) of intervention, detailing time taken to fall asleep, number of night-wakings, and estimated total sleep time. We encouraged parents/care-givers to complete diaries each morning, recalling previous night's sleep, to help optimise accuracy of information retrieved.

Parental perceptions of impact on child's general wellbeing, child's mood and behaviour, family wellbeing, confidence in child participating in future physical activity, likelihood of child participating in increased future physical activity, and interest in future sessions were sought through a Likert-scale questionnaire developed specifically for the study.

A semi-structured interview schedule relating to CanChild's "F words" [23] was additionally posed (Box 1), to relate parental views to aspects of the International Classification of Functioning, Disability, and Health.

Box 1:

- Was attending the sessions FUN for your child?
- Do you think the sessions improved your child's FITNESS?
- Do you think attending the sessions improved your child's FUNCTIONING in any way? (*everyday activities such as walking, eating & drinking, communicating, playing, school activities*)
- Did your child make any new FRIENDS during the sessions?
- Did attending the sessions help your FAMILY in any way?

### 2.4 Ethical Considerations and Consent

Ethical Considerations: Safety of the participating children was paramount in the design of the project. The team providing the intervention had extensive prior experience in delivering sports interventions for children with additional needs; the interventions were to take place at venues with which the intervention team were already familiar (as described above). A decision was taken that parents should stay on-site during the intervention sessions, but that facilities would be available for them to sit comfortably, with space for parents to entertain siblings, in the knowledge that for many families alternative childcare for other children may not be available.

Consideration was given to whether transport costs should be covered for participating families; it was decided that to test the feasibility of whether such an intervention could be translated to

future implementation on a wider scale, it was important to know whether families found the set-up acceptable, including providing transport for their child.

Ethical approval of the study protocol was granted by Cambridge South Research Ethics Committee, and the Health Research Authority (REC Ref: 18/EE/0262).

Consent: Families were invited by phone and letter to recruitment mornings on two alternative dates. Members of the research team provided families with both written information and a verbal discussion about the study. It was made clear to families that their decision to participate or not would not affect their clinical care within the service, and that they could choose to withdraw at any time by contacting any member of the research team. Any family choosing to withdraw was given the opportunity to provide feedback, however no contact thereafter was made by the research team.

Following discussion, parents/care-givers provided written, informed consent for both themselves and their child to participate in the study. Where appropriate, children completed a developmentally appropriate assent form, with picture-based information.

## **2.5 Statistical Analysis**

The primary research questions of whether provision of an exercise intervention was feasible and acceptable were assessed through descriptive analysis of the qualitative data gathered through parent-reported outcome measures.

Due to the small number of participants, statistical analysis of the quantitative data generated from the secondary questions of interest (including perceived impact on sleep patterns), was not attempted; descriptive analyses were therefore also applied to this set of data. This included use of Microsoft Excel to calculate average sleep-onset latency, total sleep time, and number of night wakings over the measured 14-night periods for individual children, and thereafter, averages for the total group in whom full data was available.

## **3. Results**

Forty-one children were initially identified from the caseload of children recently seen in the Community Paediatric Sleep Clinic. Fourteen participants were initially recruited through recruitment mornings as described above; three later withdrew (two could not commit to venue/timings; one parent required to attend other interventions). Four further participants were subsequently recruited by telephone. A total of 15 participants were therefore recruited.

Reasons for non-recruitment of the remaining 23 potential participants included:

- Contact not established-13
- Sleep improved-4
- Excluded for medical reasons (current arrhythmia/neurology investigations)-2
- Unable to commit or not interested (timings not good for family, not interested, having a baby, away during the intervention)-4

Eleven participants were male, four female. Fourteen had a diagnosis of autism-spectrum condition; eight were non-verbal; twelve had a diagnosis of Intellectual Disability; two had chromosomal disorders, one of whom also had mobility impairment. Additional diagnoses included Attention Deficit/Hyperactivity Disorder, Avoidant Restrictive Food Intake Disorder, constipation,

asthma, behaviour that challenges. All participants could walk independently. None had undergone recent surgery.

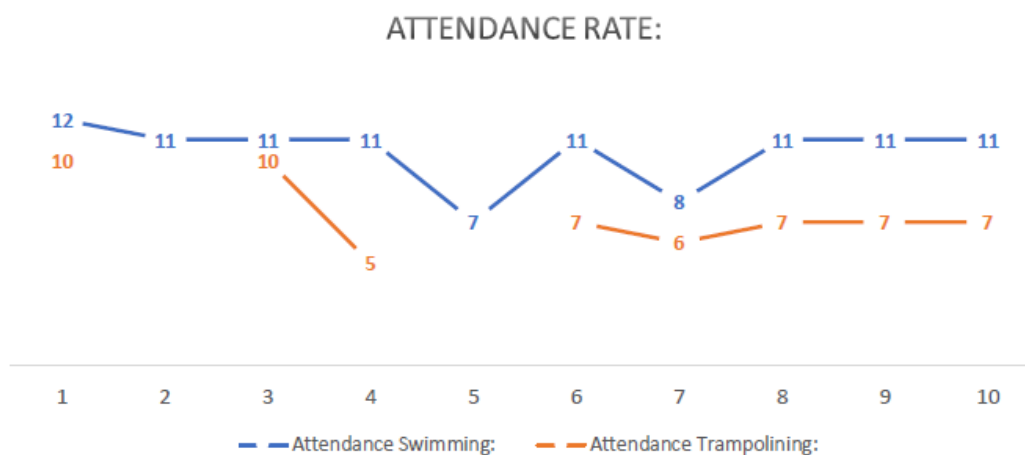
Age range was 5 years 5 months to 11 years 9 months; median 9 years 0 months.

One participant received one single telephone contact (routine planned review appointment) from the Sleep Clinic team during the course of the intervention. No other Sleep Clinic intervention was provided during the study period.

### 3.1 Primary Outcome Measures-Feasibility and Acceptability

Of the 15 children recruited, 12 attended on a regular basis. One child attended a single session, two children were not brought to any sessions. Barriers to engagement included changing parental work pattern, non-English speaking parent, domestic violence, and parental and child mental health (primarily anxiety), highlighting the range of social vulnerabilities and barriers to interventions for families in our area.

Of the remaining 12, attrition rate was very low for the swimming sessions (attendance at swimming sessions 11 out of 12 in the final weeks), but greater for the dry-sports sessions (7 out of 12 in the final weeks) [Figure 1].



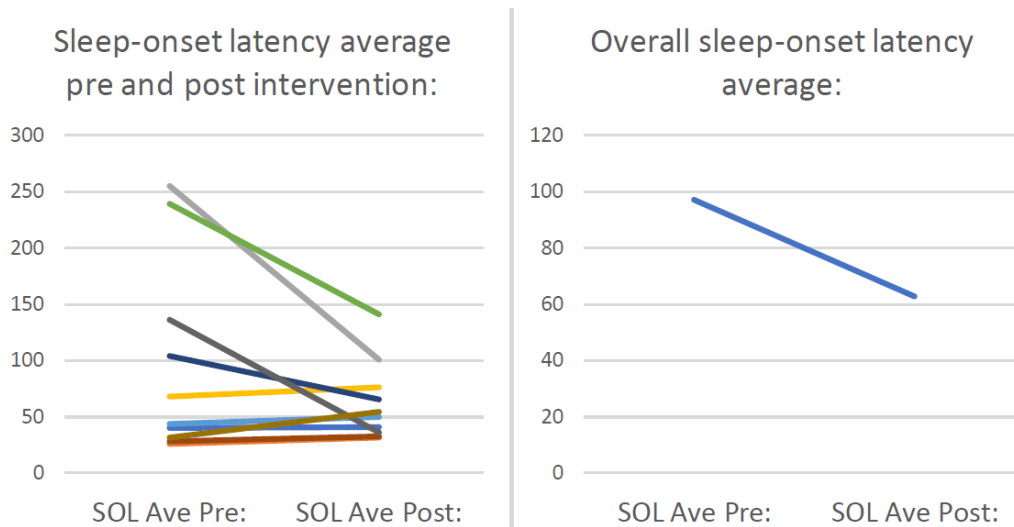
**Figure 1** Number of participants attending intervention sports sessions by week of intervention (total 15 recruited; 2 never attended. Weeks 2 and 5 of trampolining cancelled due to non-availability of venue/staff (UK Bank Holiday week 2; school half-term week 5)).

Parents who completed the outcome-measure questionnaires (N = 11; not received back from 1 participating family, and 0 of the 3 families who did not take part on a regular basis) reported the activities to be appropriate to their child’s needs (Swimming: 9 very appropriate, 1 somewhat appropriate, 1 not answered. Dry-sports: 8 very appropriate, 1 somewhat appropriate, 2 not answered).

### 3.2 Secondary Outcome Measures-Impact on Sleep and Wellbeing

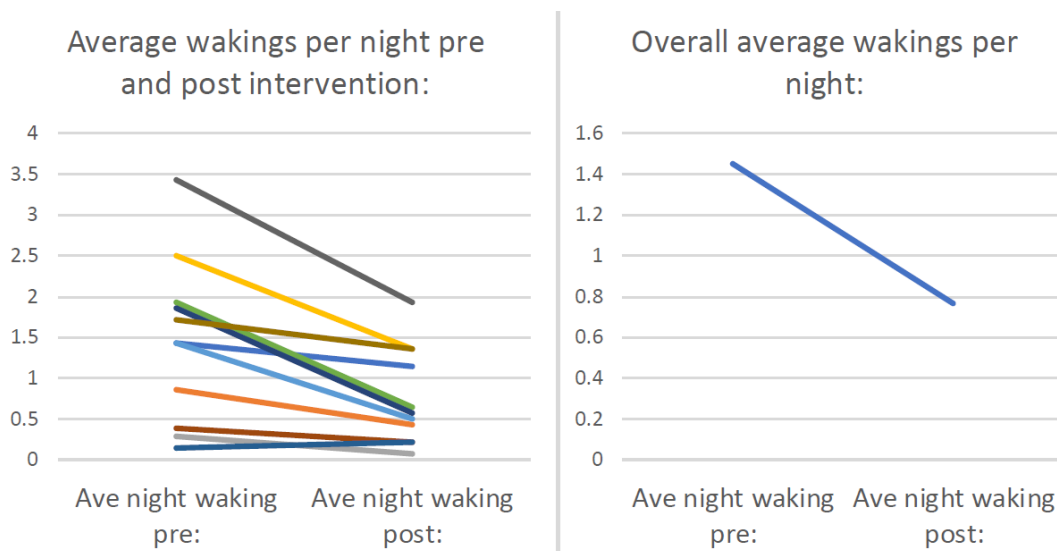
Data from sleep-diary reporting was fully available for 10 out of the 12 children who completed the intervention.

Reported sleep-onset latency (time to fall asleep) fell on average from 97.1 minutes pre-intervention, to 62.8 minutes at end-of-intervention [Figure 2].



**Figure 2** Sleep-onset latency (SOL) pre- and post- intervention in minutes (average over 14 nights).

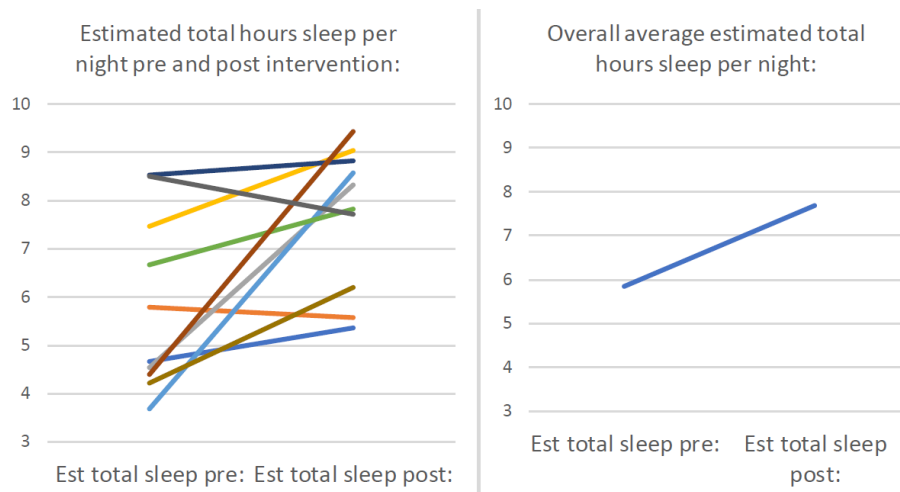
Number of night-wakings improved in all but one child; overall reduction from average 1.45 wakings per night pre-intervention, to 0.77 wakings per night at end-of-intervention [Figure 3].



**Figure 3** Number of night-wakings per night (average over 14 nights).

Estimated total sleep duration increased for 8 out of 10 children in whom full data was available; 6 children achieved more than a reported additional one hour of sleep per night, and perceived total sleep duration doubled or almost doubled for some (3.7 to 8.6 hours; 4.4 to 9.4 hours; 4.5 to 8.3 hours). Overall average perceived sleep duration increased from 5.8 hours per night pre-intervention, to 7.7 hours per night at end-of-intervention [Figure 4].





**Figure 4** Estimated total hours sleep per night (average over 14 nights).

Through Likert-scale questionnaire, 10 parents reported improvements in their child’s sleep pattern (2 improved a great deal; 2 improved a lot; 6 improved a bit), general wellbeing (3 improved a great deal; 1 improved a lot; 6 improved a bit), and family wellbeing (2 improved a great deal; 3 improved a lot; 5 improved a bit); 9 reported positive impacts on their child’s mood and behaviour (3 improved a great deal; 2 improved a lot; 4 improved a bit) [Table S1].

Parental *confidence* in their child participating in more physical activity in the future improved in all families (5 “extremely confident” about child doing more physical activity in the future; 1 “very confident”; 5 “more confident”), and reported *likelihood* of child engaging in more physical activity in the future improved in all families who responded (4 “certain” of child engaging in physical activity in future; 5 “more likely” child will engage in more physical activity in future; 2 not answered) [Table S1].

Free-text feedback was overwhelmingly positive; answers from all free-text comments were grouped according to the “F-words” as presented below.

**FUN:**

*“Before the session I would tell him that we are going to swim or to jump, he would reply with positive emotion”*

*“He enjoyed it and looked forward to going each week”*

*“She loves it so much”*

*“We were happy because my child enjoyed these sessions. She used to come home with excitement”*

**FITNESS:**

*“He seems fitter and a lot more willing to do activities”*

*“No, still the same, but he is growing and maybe he will do more physical activities”*

**FUNCTIONING:**

*“I have noticed a big change in my child over the 10 weeks, he has gained water confidence, he is also more sociable”*

*“Over the 10 weeks we have had a much better sleep pattern, we have had a lot less meltdowns, and he is generally a lot calmer”*

*“Improved playing with others in terms of those activities. Socialising. There has been good improvement on their sleep pattern”*

**FRIENDSHIPS:**

*“Not with the children, but with the adults!”*

*“It is nice to see him interacting with faces he isn’t so familiar with”*

**FAMILY:**

*“This has been great for me as a parent to know what activities works for my children”*

*“It has given us the confidence that [he] can do it!”*

*“Yes, after the sessions my son comes home, he sleeps well and wake up in the morning normal time, and less stress for us”*

*“I am happy to be part of this [study] for my son, and for him to do the activities where his needs are met and understood”*

*“This is so good for him and our mood”*

One family’s child slept through the night for the first time in his life, another family described having tried to teach their child to use a push-along scooter for 18 months, and mastering the skill during the 10 week intervention. Functional changes were also noticed by parents in children’s eating (improved appetite and motivation), communicating, requesting, and playing with others.

Sports instructors noted improvements in coordination, balance, agility, water confidence, ease of communication with children, ability to separate from parents to carry out activities independently, and motivation to participate in physical activities. The team lead commented, “Most of all it was amazing to see the clients getting so much enjoyment from the activities, and smiling and laughing through the majority of the sessions”.

Children who could verbally communicate were asked for their impressions of the sessions; responses included *“It’s fun!”* and *“Wow!”*

Parental feedback on potential improvements or changes to the sessions fell into 3 categories:

*Availability:* 3 families commented on wanting the sessions to continue, increasing the number of sessions available, asking the Local Authority to provide more activities like this suited to children with additional needs

*Timing:* one family thought an earlier time would be better; one family commented there could be better spacing of activities throughout the week; one family felt 1.5 hours of swimming was too much for their child

*Location:* Two families felt the sessions were too far away; one family highlighted parking restrictions made it difficult to drive to the swimming venue

All families were interested in attending further sessions if these were to be offered in the future.

**4. Discussion**

The benefits of adequate sleep on health and functioning are well established, however achieving adequate sleep for individuals with neurodevelopmental disorders, and their families, remains a challenge. In our cohort, no participant was achieving average sleep duration within the recommended range of 9-12 hours sleep per night (for children aged 6-12 years) at the beginning of the study period (all achieving <9 hours average per night pre-intervention).

Recommendations to support healthy sleep include having a healthy level of physical activity, however data in relation to the impact of physical activity on sleep patterns in children with neurodevelopmental disorders remains scarce, highlighting the need for further research targeting this area. There is as yet no consensus on the “dose” of physical activity that should be aimed for,

with multiple methodological approaches reported previously [24]. High-intensity exercise appears to be specifically beneficial to sleep patterns in *typically developing* children [12], suggesting that dose may indeed be important. Previous available studies in children *with neurodevelopmental disorders* have examined the impact of *general* physical activity levels on sleep patterns [19], and introduction of short-term (e.g. 3 week duration) structured physical activity [20].

We sought primarily to explore the feasibility, and acceptability to families, of implementation of a 10-week physical activity programme comprising weekly sessions of both swimming and dry sports, designed and delivered by a team of sports instructors experienced in delivering physical activity interventions for children with additional needs. As secondary questions of interest, we sought to explore parental perceptions of the impact of the intervention on their child's sleep, areas of wellbeing, and family wellbeing - areas highlighted as needing further exploration by previous researchers.

Implementation and completion of the intervention supported feasibility from a *provider* perspective, however we acknowledge the cost of provision of an adequately-supervised exercise programme for children with disabilities may present a barrier to *commissioning* of interventions that meet the needs of this group. The vast majority of the intervention cost was in the human resource required to provide a 1-to-2 staff-to-child ratio, deemed important for adequate supervision/safety, and to facilitate optimal participation of the child.

Evaluating true cost-effectiveness requires balancing the immediate cost of intervention, with potential cost-savings in relation to crisis services accessed by families (Local Authority respite care, Child and Adolescent Mental Health Services, parental mental health services). A recent literature review [25] highlighted the substantial costs of supporting a child with Autism Spectrum Disorder both directly (education, healthcare, accommodation, respite care, therapy) and indirectly (lost productivity), demonstrating the importance of acknowledging these factors in economic evaluation of interventions.

Acceptability of the intervention was supported by overwhelmingly positive feedback from those families that could take part. There were, however, persisting barriers to engagement with interventions of this sort, with 3 of 15 recruited families not completing the intervention, with a range of social factors contributing to this. In addition, a higher attrition rate for the dry-sports sessions appeared to be related to transport difficulties for this particular venue (lack of easily accessible public transport reported through free-text comments), highlighting additional persisting structural barriers to access for some families.

Our secondary questions of interest were related to the impact of such an intervention on child's sleep and wellbeing, and family wellbeing, as perceived by parents/care-givers. Parents reported positive changes in sleep patterns for participating children, with two participants reaching the recommended sleep duration for this age group of average >9 hours per night, and number of reported night wakings halving on average. Almost all families reported positive impacts on general wellbeing, mood and behaviour, functional skills, and family wellbeing. Although this was a small-scale study, and not powered to assess the statistical significance of reported changes to sleep patterns, our findings are in keeping with previous studies in both typically developing children and those with neurodevelopmental disorders, suggesting physical activity plays a role in improving sleep health.

We speculate that provision of safe, structured, cost-free physical activity sessions may support overall family physical activity levels, increased time spent out of doors (through associated travel),

and confidence in engaging with physical activity. Through this, we hypothesise that sleep and wellbeing patterns may be positively impacted indirectly in the longer term. It has been shown that providing structured physical activity interventions can increase level of physical activity beyond the immediate intervention period [26], and future studies evaluating this in children with neurodevelopmental disabilities will add to the data for this vulnerable group.

*Limitations of the study:* Parent-reported measures can carry a risk of reporting bias, however sleep diaries have been described as the gold standard for subjective reporting of sleep, with good reliability when compared to actigraphy measurement, if completed for at least 5 nights [27]. Additionally, parents' perceptions and experiences of their child's sleep are arguably the most important outcome measure when supporting a child with additional needs in the context of their family setting.

This small-scale study, designed primarily to assess feasibility and acceptability of the intervention, was not powered to assess statistical significance of the secondary research questions. We sought to minimise burden to participating families, and use of purposively designed Likert-scales carried simplicity, ease of completion, and minimal time resource for participating parents.

Additionally, the study was not designed to take account of potential confounding factors, including social, environmental, behavioural and family influences on sleep patterns, although we are confident that the participants were not receiving other interventional support from our service during the course of the study, and therefore the only change from a service perspective was introduction of the physical activity sessions.

Following this feasibility study, further research is required to draw more definitive conclusions, including studies evaluating exercise as a complex intervention in children with neurodevelopmental disorders, adequately powered comparative studies using validated objective measures of activity-intensity achieved and sleep patterns, and health economic evaluation of such interventions.

*Final note:* In times of resource limitation, gathering data on interventions that families find beneficial is imperative, especially for vulnerable patient groups, for whom robust evidence-based guidance is often lacking, partly due to ethical dilemmas in undertaking research in vulnerable cohorts [28]. In the United Kingdom, Community Child Health teams work primarily with children who have developmental or social vulnerabilities; such teams should feel encouraged to broaden the evidence base through analyses of quality improvement projects within their departments, helping strive towards best possible care and interventions for our patient population within increasingly limited resources.

## **5. Conclusions**

This small-scale study has shown that delivery of an exercise intervention appropriate for children with significant neurodevelopmental disorders in our area is possible, and highlights the potential wide-reaching benefits of an intervention initially conceived to support one aspect of health (improved sleep health for child), that has returned positive impacts on areas of the child's functioning, mood, behaviour, and family wellbeing.

Participating families reported shorter average sleep-onset latency (time taken to fall asleep), fewer average night-wakings, and longer average sleep duration in their participating children, with

improvements to general wellbeing, mood, behaviour, and areas of functioning reported to have been seen over the course of the 10 week intervention.

Families who took part appreciated the opportunity to access physical activity sessions that met the needs of their children with neurodevelopmental disabilities, and all were all interested in attending future sessions if the opportunity were to arise again, suggesting the value of such interventions to families.

There are, however, persisting barriers to participation in physical exercise for children with neurodevelopmental disabilities, and endeavours to minimise these will continue to be important in the design of future research and interventions.

Key messages:

- Development of an exercise-based intervention for children with neurodevelopmental disorders has been very well received by families who took part
- Parents reported positive impacts on sleep, wellbeing, and daily functioning following the intervention
- Parents reported increased likelihood of child doing physical activity after taking part, highlighting the potential longer-term impacts of such an intervention

## **Acknowledgments**

With many thanks to the London PE and School Sports Network for providing the intervention for this study.

## **Additional Materials**

The following additional materials are uploaded at the page of this paper.

1. Figure S1: Sleep Diary.
2. Table S1: Parent-reported Likert-scale measures.

## **Author Contributions**

JT designed the project, recruited participants, collated and analysed data, drafted the initial manuscript, edited the final version of the manuscript, and gave final approval for publication of the manuscript. JVL supported the design and running of the project, completed applications for REC and HRA approvals, recruited participants, reviewed and edited the initial manuscript, and gave approval for publication of the final manuscript. SH supported the design and running of the project, edited the initial manuscript, and gave approval for publication of the final manuscript. All authors agree to be accountable for the work and data presented.

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## Competing Interests

The authors have declared that no competing interests exist.

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