Comparison of Patterns of Physical Activity and Sedentary Behavior Between Children With Cerebral Palsy and Children With Typical Development

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Background. Reduced participation in physical activity and increased time spent in sedentary behavior are associated with overweight, chronic disease, and disability. In order to optimize recommendations and interventions to increase physical activity and reduce sedentary behavior in children with cerebral palsy (CP), knowledge of their physical activity and sedentary behavior is needed.

Objectives. The aim of this study was to describe light, moderate, and vigorous physical activity and sedentary behavior in preadolescent children with and without CP and compare physical activity and sedentary behavior between the 2 groups.

Design. This was a cross-sectional study of 33 children, aged 6 to 10 years, with CP (Gross Motor Function Classification System [GMFCS] levels I–III) and 33 age- and sex-matched children with typical development.

Methods. Physical activity was measured using the RT3 accelerometer over 7 days.

Results. Children with CP spent more time in sedentary behavior and accumulated less total activity, moderate activity, vigorous activity, and sustained bouts of moderate-to-vigorous activity (MVPA). They also accumulated a fewer number of bouts of MVPA and vigorous activity, despite spending a similar amount of time in each bout.

Limitations. The small number of children in GMFCS levels II and III did not allow for adjustment for GMFCS level when comparing physical activity between children with and without CP.

Conclusions. Preadolescent children with CP spent less time in moderate and vigorous activity and more time in sedentary behavior than children with typical development. Children with CP also accumulated less continuous MVPA and vigorous activity as a result of achieving fewer sustained bouts of MVPA and vigorous activity throughout the day.

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Physical activity is defined as "any bodily movement produced by skeletal muscle that results in energy expenditure."[1(p126)] Reduced participation in physical activity is associated with stroke, coronary heart disease, type 2 diabetes mellitus, and disability.[2–4] It is well established that people with cerebral palsy (CP) participate in low levels of habitual physical activity.[5,6] These low levels of habitual physical activity may have a detrimental effect on their physical, behavioral, and emotional health[6,7] and contribute to a downward spiral of physical deconditioning, poor physical functioning, and physical inactivity.[8–10] People with CP also spend a large proportion of their day in sedentary behavior.[6,11] Although, traditionally, the terms "sedentary behavior" and "physical inactivity" (ie, the absence of physical activity) were used interchangeably, sedentary behaviors are "a distinct class of behaviors (eg, sitting, watching TV, driving) characterized by little physical movement and low energy expenditure."[12(p727)] A person may be both sedentary and physically active. Prolonged sedentary behavior is negatively associated with a number of risk factors for chronic disease, including increased waist circumference, dyslipidemia, and insulin resistance,[13,14] and recent physical activity recommendations advise that children minimize time spent in sedentary behavior.[15]

Although the recommendation to minimize sedentary behavior is relatively new, it has been recommended that children participate in 60 minutes of moderate-to-vigorous physical activity (MVPA) daily since the late 1990s.[16] This recommendation was primarily based on information from intervention studies, as quantification of habitual physical activity was limited by a lack of accurate and feasible methods of assessing physical activity throughout the day. The advancement of accelerometry in quantifying habitual physical activity in the last decade has enabled us to further investigate the relationship between habitual physical activity and cardiovascular health. The most recent guidelines from the World Health Organization (WHO) incorporate the knowledge obtained from studies that used accelerometry to measure physical activity.[17] As a result, the WHO guidelines recommend that children achieve 60 minutes of MVPA daily, but it is emphasized that this time in MVPA should be acquired in addition to activities of daily living.[17] When measured with accelerometry, activities of daily living total around 30 to 40 minutes of MVPA in children per day,[18] suggesting that the WHO recommendations constitute a significant increase in the recommended level of MVPA for children.[19] Therefore, if accelerometry is used to measure daily activity, we suggest that children should accumulate approximately 90 minutes of MVPA daily.

In the general population, there is a steep decline in physical activity from childhood to adolescence.[20,21] This decline appears to be magnified in CP,[22] possibly as a result of a decline in gross motor function during adolescence and a reduction in services as adolescents transition from pediatric to adult rehabilitative services.[23,24] A recent study showed that adolescents and young adults with CP spend less time in objectively measured physical activity and more time in sedentary behavior than their peers with typical development.[25] It is still unclear, however, if differences in physical activity and sedentary behavior exist between children with and without CP prior to adolescence.

Using the StepWatch Activity Monitor (Cyma Corp, Mountlake Terrace, Washington) to measure walking activity, Bjornson et al[26] found that children with CP between 10 and 13 years of age demonstrated lower daily steps, a lower percentage of time in activity, and a lower percentage of time at high activity levels than children without CP. However, the StepWatch monitor is restricted to measuring walking activity and provides limited information about the volume and intensity of physical activity. Accelerometers have an advantage of providing information about volume, intensity, and patterns of physical activity. Two studies have used accelerometry to compare physical activity and sedentary behavior between children with and without CP. Obeid et al[11] found that children and adolescents with CP between the ages of 8 and 17 years spend more time in sedentary behavior than children and adolescents without CP. Capio et al[27] reported that children with CP, with a mean age of 7.41 years, participated in less MVPA and more sedentary behavior than age-matched children without CP. However, the age range of the children was not specified.

Childhood is an important period for establishing physical activity behaviors that affect long-term cardiovascular health.[28] Positive experiences of physical activity in childhood may encourage children to remain active in adolescence and beyond. It may be particularly important for children and adolescents with CP to have positive physical activity experiences early in life, as feeling insecure about participating in sports and perceiving physical activity and sports as not being enjoyable have been identified as barriers to physical activity in this population.[29] Parents are largely responsible for providing children with opportunities to participate in physical activity, but without adequate guidance, they may not provide such opportunities. In order to optimize physical activity recommendations and to develop effective interventions to increase physical activity and reduce sedentary behavior, knowledge of physical activity behavior among preadolescent children with CP is needed. The aim of this study was to utilize accelerometry to describe light, moderate, and vigorous physical activity and sedentary behavior in preadolescent children with and without CP and compare physical activity and sedentary behavior between the 2 groups.

Method

Sample

Thirty-three children with CP (17 male, 16 female; mean age=8.5 years, SD=1.2, range=6–10) recruited from 2 national organizations that provide services to children with disabilities participated in this study. The children had unilateral spastic CP (n=20), bilateral spastic CP (n=11), and nonspastic forms of CP (n=2) and were classified in Gross Motor Function Classification System (GMFCS) level I (n=24), level II (n=4), and level III (n=5). The children were recruited as part of a larger study that investigated the

Table 1.
Definition of Physical Activity Variables[a]

Physical Activity Variable	Definition	Cutpoint (VM Counts per Minute)
Wear time (min)	Average daily wear time	NA
Sedentary behavior (min)	Average daily time spent in sedentary activity	<41
Percentage sedentary time (%)	Sedentary behavior as a percentage of wear time	NA
Light activity (min)	Average daily time spent in light activity	41–950
Moderate activity (min)	Average daily time spent in moderate activity	951–3,410
Vigorous activity (min)	Average daily time spent in vigorous activity	>3,410
Sustained moderate-to-vigorous activity (min)	Average daily time spent in ≥10-minute bouts of moderate-to-vigorous activity	>950
Number of bouts of moderate-to-vigorous activity (n)	Average daily number of ≥10-minute bouts of moderate-to-vigorous activity	NA
Number of bouts of vigorous activity (n)	Average daily number of ≥1-minute bouts of vigorous activity	NA
Mean time in each bout of moderate-to-vigorous activity (min)	Average daily time spent in each ≥10-minute bout of moderate-to-vigorous activity	NA
Mean time in each bout of vigorous activity (min)	Average daily time spent in each ≥1-minute bout of vigorous activity	NA
Mean counts per minute	Average daily VM counts per minute	NA

[a] VM=vector magnitude (VM count data collected in 1-minute epochs), NA=not applicable.

association among physical activity, sedentary behavior, anthropometric measures, and blood pressure in children with CP.[30] Children with CP were excluded if they had a severe intellectual disability or had undergone surgery in the previous 6 months. The children with CP were matched for age (within 12 months) and sex to children with typical development who participated in a previous research study that investigated the relationship among physical activity, cardiorespiratory fitness, and body composition in preadolescent children.[31] A parent or legal guardian provided written informed consent for his or her child to participate in the study.

Physical Activity

Physical activity was measured in all children using the RT3 accelerometer (Stayhealthy Inc, Monrovia, California). The RT3 is a triaxial accelerometer that measures the body's acceleration in 3 planes. It provides a count output for each plane, which is proportional to the magnitude of acceleration, and a vector magnitude count output, calculated as the square root of the sum of squared counts for each plane. Children were asked to wear the RT3 on their right hip (or least affected side in the case of significant asymmetry) in the midaxillary line. Participants wore the RT3 during waking hours and removed it for bathing, swimming, and sleeping.

Vector magnitude counts were collected for all participants in 1-minute epochs. The RT3 was connected to a personal computer, and raw data were downloaded using RT3 Assist software (Stayhealthy Inc) before being exported to and processed in Microsoft Excel 2010 (Microsoft Corp, Redmond, Washington). Wear time was calculated by subtracting nonwear time from each 24-hour period. Nonwear time was considered 10 or more minutes of consecutive 0 counts, allowing for 1 minute of 10 or fewer counts within a given 10-minute period. Participants were excluded if they had less than 3 valid wear days. Three days of monitoring is needed to achieve a reliability coefficient of .70 in children with and without CP.[32,33] Valid wear days were defined as having at least 9 hours of wear time per day.

The RT3 accelerometer cutpoints developed by Vanhelst et al[34] were used to classify sedentary behavior and physical activity intensity because, when compared with other published RT3 accelerometer cutpoints, they provide the most accurate estimate of physical activity intensity in children with and without CP.[35,36] An overview of the physical activity variables that were calculated is provided in Table 1. In order to account for differences in wear time between groups percentage, sedentary time (ie, sedentary behavior as a percentage of wear time) was calculated. When calculating sustained MVPA, 1 minute below the MVPA threshold was allowed for within a bout of 10 or more minutes of MVPA without the bout being deemed ended. However, if 2 minutes or longer below the MVPA threshold was recorded, the bout was considered ended. Mean counts per minute were calculated for each day to provide an indication of total physical activity.

Finally, to examine adherence to physical activity guidelines, the percentage of children with CP and the percentage of children with typical development who achieved 60 and 90 minutes of MVPA daily, respectively, were calculated. All moderate and vigorous activity accumulated throughout the day contributed to

Table 2.
Physical Activity Variables for Children With Cerebral Palsy and Children With Typical Development[a]

Physical Activity Variable	Children With Cerebral Palsy[b]	Children With Typical Development[b]	Difference[c]	95% CI Lower Boundary	95% CI Upper Boundary	*t*	*P*
Sedentary time (min)	193.18 (68.02)	123.23 (49.13)	69.95 (14.61)	40.77	99.13	4.789	.000
Percentage sedentary time (%)	25.15 (7.73)	17.54 (6.57)	7.61 (1.77)	4.08	11.14	4.306	.000
Light activity (min)	435.12 (49.17)	432.07 (61.08)	3.05 (13.65)	−24.24	30.34	0.824	.224
Moderate activity (min)	104.23 (4.41)	127.83 (2.68)	−1.20 (0.21)	−4.09	−0.03	−2.367	.021
Vigorous activity (min)	6.48 (1.62)	12.53 (3.41)	−0.99 (0.15)	−3.15	−0.04	−2.545	.014
Sustained moderate-to-vigorous activity (min)	50.38 (6.95)	78.17 (6.69)	−3.04 (0.41)	−9.17	−0.21	−2.712	.009
Number of bouts of moderate-to-vigorous activity (n)	2.71 (0.32)	3.79 (0.21)	−0.09 (0.02)	−0.31	−0.00	−2.369	.021
Number of bouts of vigorous activity (n)	3.86 (0.88)	6.81 (0.88)	−0.41 (0.05)	−1.22	−0.04	−2.797	.007
Mean time in each bout of moderate-to-vigorous activity (min)	18.29 (0.16)	20.25 (0.29)	0.05 (0.01)	−0.21	0.00	−1.897	.063
Mean time in each bout of vigorous activity (min)	1.63 (1.74)	1.66 (1.40)	−1.01 (1.12)	−0.79	1.24	−0.121	.904
Mean counts per minute	482.88 (168.08)	634.81 (190.27)	−151.94 (44.19)	−240.23	−63.65	−3.438	.001

[a] CI=confidence interval.
[b] Data presented as mean (SD).
[c] Data presented as mean (standard error).

the attainment of physical activity guidelines, as guidelines for children, unlike those for adults, do not state that MVPA should be accumulated in ≥10-minute bouts.[17]

Data Analysis

The Kolmogorov-Smirnov test was used to test for normally distributed data. Number of valid wear days, moderate activity, vigorous activity, sustained MVPA, number of bouts of MVPA, number of bouts of vigorous activity, mean time in each bout of MVPA, and mean time in each bout of vigorous activity were not normally distributed. A logarithm transformation was used to transform mean time in bouts of vigorous activity to a normal distribution. A square-root transformation was used to transform moderate activity, vigorous activity, sustained MVPA, number of bouts of MVPA, number of bouts of vigorous activity, and mean time in each bout of MVPA to a normal distribution. A Mann-Whitney *U* test was used to compare number of valid monitoring days between groups. Physical activity variables were compared between children with CP and children with typical development using independent *t* tests. The Fisher exact test was used to compare the number of children with CP and the number of children with typical development who achieved 60 and 90 minutes of MVPA daily, respectively. Statistical significance was set at α=.05.

Results

Children with CP wore the RT3 for a median time of 7 days (range=4–8, interquartile range [IQR]=1) and a mean duration of 741.7 minutes per day (SD=54.1). Children with typical development wore the RT3 for a median time of 4 days (range=3–6, IQR=1) and a mean duration of 701.5 minutes per day (SD=74.5). There was no difference in the number of valid wear days between groups. However, children with CP wore the RT3 for a longer duration per day (*P*=.02).

Physical activity variables for children with CP and children with typical development are presented in Table 2. Children with CP spent more time in sedentary behavior and percentage sedentary time (*P*<.001 for both) and accumulated less total activity (*P*<.01), less moderate activity (*P*<.05), less vigorous activity (*P*<.05), and less sustained MVPA (*P*<.01) than children with typical development. Children with CP also accumulated fewer bouts of both MVPA and vigorous physical activity than children with typical development (*P*<.05 and *P*<.01, respectively). However, there was no difference in mean time in each bout of MVPA or vigorous activity between children with CP and children with typical development. The percentage of children achieving 60 and 90 minutes of MVPA daily, respectively, is presented in the Figure. Thirty-one children with CP achieved 60 minutes of MVPA daily. This finding was not significantly different from the number of children with typical development achieving 60 minutes of MVPA daily (n=32). However, significantly more children with typical development achieved 90 minutes of MVPA daily than children with CP (n=31 versus n=22, respectively) (*P*=.01).

Discussion

The aim of this study was to utilize accelerometry to describe light, moderate, and vigorous physical activity and sedentary behavior in preadolescent children with and without CP and compare physical activity and sedentary behavior between the 2 groups. The results indicate that children with CP between the ages of 6 and 10 years spend more time

in sedentary behavior and less time in total activity, moderate activity, vigorous activity, and sustained MVPA than their peers with typical development. Interestingly, reduced participation in vigorous activity and sustained MVPA was a result of children with CP accumulating fewer bouts of vigorous activity and MVPA throughout the day, rather than spending less time in each bout. Although a large proportion of children with CP met the physical activity recommendation of 60 minutes of MVPA daily, considerably fewer children with CP achieved 90 minutes of MVPA per day.

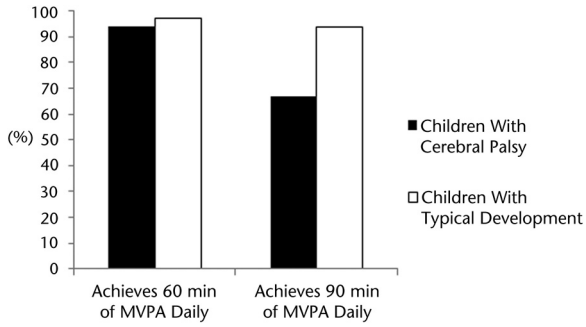

Figure.
Percentage of children with cerebral palsy and children with typical development who accumulated 60 and 90 minutes of moderate-to-vigorous physical activity (MVPA) daily.

Although the methods used to measure physical activity vary across studies, the results of this study are in agreement with studies by Bjornson et al[26] and Capio et al,[27] who found that children with CP participated in less MVPA, accumulated less daily walking activity, and accumulated less high-intensity walking activity than children with typical development. However, unlike previous studies, we compared time spent in each component of physical activity between children with and without CP, rather than comparing walking activity or combined MVPA only. As such, to our knowledge, this is the first study to indicate that children with CP, in GMFCS levels I through III, participate in less objectively measured vigorous activity than children with typical development. This finding supports the results of a previous comparison of self-reported vigorous activity between children with and without CP.[37] The use of an objective measure of physical activity in the current study strengthens this conclusion. Although self-report measures have traditionally been used to measure physical activity, primarily because they are a feasible and relatively inexpensive method of collecting data on large samples, they may significantly overestimate physical activity in young people.[38] Furthermore, the accuracy of self-report measures may be particularly poor in children younger than 10 years because of reduced cognitive ability to recall activity from the past and dependence on parents or teachers for information.[39]

Reduced participation in vigorous activity may have significant health implications for children with CP. In children with typical development, participation in vigorous activity, but not moderate activity, is associated with lower body mass index (BMI), lower waist circumference, lower systolic blood pressure, and higher cardiorespiratory fitness.[40,41] Similarly, reduced participation in vigorous activity, but not moderate activity, is associated with elevated blood pressure in children with CP.[30] Hay et al[40] noted a reduced odds ratio of overweight and elevated systolic blood pressure when children achieved more than 7 minutes of vigorous activity daily. Children with CP in the current study accumulated, on average, 6 minutes of vigorous activity daily, significantly less than the 12 minutes accumulated by children with typical development.

Although physical activity recommendations from the United States, England, Scotland, Wales, and Northern Ireland recommend that children and young people participate in vigorous-intensity activities on at least 3 days each week,[15,42] further evidence is needed to formulate a specific guideline for vigorous activity in children with and without CP. There is a particular need for further investigation of the relationship between cardiovascular risk, including overweight/obesity and vigorous activity in children with CP. A previous study showed that BMI, waist circumference, and waist-height ratio were not related to any physical activity variable in children and adolescents with CP.[30] Indeed, despite children in GMFCS level III participating in reduced levels of physical activity and spending increased time in sedentary behavior, in comparison with children in GMFCS levels I and II,[30] overweight/obesity and elevated blood pressure among children in level III were relatively low.[30,43] Although this finding suggests that the relationship between physical activity and cardiovascular risk may differ across GMFCS levels, the discrepancy may be due to the inability of BMI to accurately indicate body fat or cardiovascular risk in children with moderate-to-severe physical impairments.[44–46]

The results of this study support recent findings of excessive sedentary behavior among children and adolescents with CP compared with their peers with typical development.[11,25] In the current study, children with CP spent, on average, 7.6% more time in sedentary behavior each day than children with typical development. Similar results were found in a population of adolescents and young adults with CP who spent approximately 5.5% more time in sedentary behavior compared with adolescents and young adults without CP.[25] The incorporation of a guideline on minimizing sedentary behavior into recent physical activity recommendations for children and young people[15] highlights the importance of minimizing sedentary behavior in order to optimize cardiovascular health. There is emerging evidence that prolonged sedentary behavior is associated with overweight/obesity and metabolic dysfunction in children and young people with typical development.[47,48] Sedentary behavior also is associated with elevated blood pressure in children and adolescents with CP.[30] In addition to spending

increased time in sedentary behavior, children with CP take fewer breaks from sedentary time.[11] Breaking up sedentary behavior with short bouts of light activity may be an effective method of minimizing sedentary time and improving cardiometabolic health in children with CP.[13,49,50]

The current physical activity recommendation states that children should accumulate at least 60 minutes of MVPA daily in addition to activities of daily living.[17] Studies using accelerometry suggest that the quintile of least active children may accumulate 30 to 40 minutes of MVPA during activities of daily living.[18] Therefore, when habitual physical activity is measured with accelerometry, 90 minutes is arguably a more accurate representation of meeting the current guidelines than 60 minutes.[19] Indeed, clustered cardiovascular risk was raised in 9-year-old children with typical development who accumulated less than 116 minutes of daily habitual MVPA.[18] Children with CP in this study accumulated on average 111 minutes of MVPA daily. However one-third of the children with CP achieved less than 90 minutes of MVPA daily, significantly fewer than children with typical development.

This is the first study to demonstrate that children with CP spend less time in sustained bouts of MVPA and vigorous activity and that this is a result of achieving fewer bouts throughout the day rather than bouts being shorter in duration. Children who participate in less sustained MVPA and vigorous activity are more likely to be overweight, regardless of the total volume of MVPA they accumulate.[51,52] Accumulation of fewer bouts of MVPA is also associated with overweight/obesity, regardless of total volume of MVPA.[51,53,54] This finding has significant implications for the development of recommendations and interventions to increase physical activity in children with CP. It suggests that children with mild-to-moderate CP may have fewer opportunities to participate in MVPA throughout the day or fail to exploit existing opportunities. This hypothesis is supported by previous reports that children with CP participate in less organized physical activity than children without CP, regardless of their level of motor impairment.[55,56] This finding may be due to several factors, including lack of opportunities, lack of sports teams to suit the child's ability, difficulty accessing facilities, feelings of insecurity, lack of motivation, and the perception that sports are difficult and not enjoyable.[29] It is clear that if interventions are to be effective at increasing participation in physical activity among children with CP, these barriers need to be addressed and opportunities for participation in physical activity need to be created.

There is some evidence that school-based, multicomponent interventions that include the family may increase physical activity in adolescents with typical development,[57] but the research is inconclusive for children.[57,58] A recent study showed that a multicomponent intervention, consisting of physical activity counseling, home-based physical therapy, and fitness training, was not effective at increasing physical activity in children with CP.[59] Increasing habitual physical activity among children with CP remains a challenge. From a health promotion perspective, reducing sedentary behavior may be a more feasible method of preventing chronic disease risk in children with CP. Furthermore, interventions aimed at reducing sedentary behavior are effective at not only reducing sedentary behavior but also reducing BMI in children and adolescents with typical development.[60,61] Future studies should investigate the efficacy of interventions that incentivize or encourage children and adolescents with CP to spend less time in sedentary behavior.

Limitations

A large proportion of children in this study were classified in GMFCS level I. The small number of children in GMFCS levels II and III did not allow us to adjust for GMFCS level when comparing physical activity between children with and without CP. In addition, the results of this study may not be extrapolated to all children with CP (ie, those in GMFCS levels IV and V).

A limitation of using a single set of cutpoints to classify PA intensity among all participants is that the cutpoints may have underestimated the volume of MVPA that children in GMFCS level III accumulated. Children in level III use significantly more energy to walk at a given speed compared with children in GMFCS levels I and II.[62] Therefore, their movement may have been incorrectly classified as light activity when it could have been moderate activity. However, cutpoints specific to each GMFCS level do not currently exist for any accelerometer.

Three or more days of valid physical activity data was needed for analysis; however, a criterion number of weekend days and weekdays of monitoring was not defined. It is possible, therefore, that some children wore the accelerometer on both weekend days and weekdays, whereas others may have worn it on weekdays only. Because physical activity patterns are known to differ between weekdays and weekends,[33] this could be considered a limitation of the study.

Finally, as convenience sampling was used to recruit participants, it is possible that children from families with an interest in being physically active volunteered to participate in this study in order to receive information on their physical activity levels. This factor may have resulted in volunteer bias and a sample that is unrepresentative of the general populations of children with and without CP. However, it is interesting to note that, despite potential volunteer bias, children with CP still spent less time in physical activity and more time in sedentary behavior than their peers with typical development.

In conclusion, preadolescent children with CP spent less time in moderate and vigorous activity and more time in sedentary behavior, as measured by accelerometry, than their peers with typical development. Physical activity behaviors are often established during childhood. It is concerning that patterns of increased sedentary behavior and reduced physical activity may be established among children with CP from a young age, as such patterns may have long-term health consequences. Children with CP also accumulated less sustained MVPA and vigorous activity as a result of achieving fewer

bouts of MVPA and vigorous activity throughout the day. It is imperative that the number of opportunities for children with CP to participate in physical activity from a young age be increased.

Dr Ryan, Dr Hussey, and Dr Gormley provided concept/idea/research design. All authors provided writing. Dr Ryan, Dr Forde, and Dr Hussey provided data collection and analysis. Dr Gormley and Dr Hussey provided project management, facilities/equipment, and institutional liaisons. Dr Forde, Dr Hussey, and Dr Gormley provided consultation (including review of manuscript before submission).

Ethical approval for this study was obtained from the Faculty of Health Sciences' Ethics Committee, the Central Remedial Clinic's Ethics Committee, and Enable Ireland's Research Ethics and Quality Committee.

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