Chapter 3

Walking activity of children with cerebral palsy and children developing typically: a comparison between the Netherlands and the United States

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Abstract

Purpose

To compare walking activity of children with and without CP between the Netherlands and the United States.

Methods

A cross-sectional comparison study including a convenience sample of 134 walking children aged 7-12 years with spastic CP, classified as Gross Motor Function Classification System (GMFCS) level I (n=64), II (n=49) or III (n=21), and 223 typically developing children (TDC) from the Netherlands and the United States. Walking activity was assessed during a one-week period using a StepWatch™ activity monitor. Outcomes were the daily number of strides, daily time being inactive and spent at low (0-15 strides/minute), moderate (16-30 strides/minute) and high stride rate (31-60 strides/minute). Walking activity was compared between countries using multiple linear regression analyses.

Results

Walking activity of TDC was not significantly different between countries. Compared to their American counterparts, Dutch children in GMFCS level I and II showed less walking activity ($p<0.05$), whereas Dutch children in GMFCS level III showed more walking activity ($p<0.05$).

Conclusion

The absence of differences in walking activity between Dutch and American TDC, and the presence of differences in walking activity between Dutch and American children with CP suggest that between-country differences affect walking activity differently in children with CP.

Introduction

Physical inactivity has become the fourth leading cause of mortality in the world, resulting in world-wide attention for the promotion of physical activity already at young age.[1] Large discrepancies in activity levels seem to exist between countries among children who are developing typically,[2,3] providing insight in the influence of culture and politics on children's physical active behavior. However, no direct comparisons in physical activity between countries have been made for children with a physical disability, who often experience challenges with participating in physical activities.[4] Increased understanding of differences in physical activity between countries may be useful for the development of activity stimulation programs for children with a physical disability.

The most common cause of physical disabilities in pediatric rehabilitation is cerebral palsy (CP).[5] This is an umbrella term for disorders in the development of movement and posture, causing activity limitations, as a result of non-progressive disturbances in the infant brain.[6] Previous studies have shown decreased physical activity of children with CP compared to children developing typically,[7] and a widening gap when mobility problems increase.[8,9] In addition, physical activity levels of Dutch children with CP have been shown to be lower during the weekend than during schooldays.[9] Physical activity levels of children with CP have been reported for The Netherlands,[9-12] the United States,[13,14] and Australia.[15,16] However, direct comparisons between countries are limited by varying assessment methods (questionnaires, pedometers, doubly-labeled water technique, and activity monitors) and different age categories.

Methods to assess physical activity can be divided into subjective and objective methods. Subjective instruments, such as questionnaires, rely on self-reported physical activity, they are cheap and they are easy in their use. These advantages have to compete against the disadvantages of socially desired answering and recall bias.[17] In particular, the short bursts of activities at high intensity, which are typical during childhood,[18] may be hard to recall. Furthermore, cultural differences may influence the interpretation of the questionnaires, which hinders comparison of physical activity between different countries.[19] The objective and real-time assessment of physical activity by means of

activity monitoring has been suggested to address these limitations.[19,20] A device that has been used to assess walking activity of children with CP is the StepWatch™ Activity Monitor (StepWatch™).[8,9,14] This ankle-worn bi-axial accelerometer registers strides per self-selected time interval, also providing information on the intensity of walking during the day. The advantage of this device is the ability to adjust the sensitivity settings of the accelerometer to accurately register strides for the pathological walking patterns as found in children with CP.

Physical activity of children developing typically is associated with environmental characteristics, such as more green space and less heavy traffic in the neighborhood.[21] Since physical activity levels of children developing typically differ between countries, differences in environment may play a role. American children have been repeatedly shown to have lower physical activity levels compared to European children.[2] Possible explanations provided by these authors are the American car-oriented lifestyle and environment, while European environments are more designed for walking and biking.[2] In addition, Vincent et al. explained their higher physical activity levels in Swedish children compared to Americans by the different organization of school day-activity (less in-class time and more activity breaks in Sweden), and more participation in after-school sports clubs in Sweden.[22] Apparently, environmental and political differences influence physical activity levels of children developing typically. Whether this also counts for children with CP is not yet investigated, illustrating the need for the present study.

The primary aim of this study is to compare walking activity on school days and on weekend days of children with cerebral palsy and an age and gender matched sample of children developing typically between the Netherlands and the Pacific Northwest of the United States. We hypothesize that children with CP, like children developing typically, are more active in the Netherlands than in the Pacific Northwest of the United States, and that children with CP are less active than their typically developing counter parts in both countries.

Methods

Design

This cross-sectional international comparison study combined Dutch and American walking activity data, assessed with a StepWatch™ activity monitor (see below), of children with spastic cerebral palsy and children developing typically in the age of 7-12 years. Both countries comprised a convenience sample. The Dutch walking activity data of children with CP was collected during the baseline assessments of a trial evaluating either a physical activity stimulation program,[23] or a lower extremity strength training for children with spastic CP aged 7-12 years.[24] The American data was derived from cross-sectional studies on walking activity in the Pacific Northwest of the United States among children with CP aged 2-13 years.[8,13] In both countries the children developing typically were matched to the children with CP based on age and gender.[25] Walking activity data was collected between 2004 and 2012. All Dutch studies were approved by the Medical Ethical Board of the VU University Medical Center Amsterdam in the Netherlands. The American studies were approved by the Institutional Research Board of the Seattle Children's Research Institute. All parents, and children aged 12 years and older, agreed upon voluntary participation in these studies and signed an informed consent.

Participants

The inclusion criteria for this comparison study were: age 7 to 12 years, having spastic CP, and being able to walk independently with or without aids as classified in level I-III on the five-level Gross Motor Function Classification System[a] (GMFCS).[26] General exclusion criteria were: contra-indications for physical training, instable seizures, and surgery in the past 6 months. Children were included in the analysis if walking activity was recorded for a minimum of four days, of which at least one weekend day.

Outcome measures

Walking activity was assessed with the StepWatch™ Activity Monitor 3.0 (StepWatch™) (Orthocare Innovations, Seattle, WA, United States) which is an ankle-worn bi-axial

[a] GMFCS I: Walking without limitations; GMFCS II: Walking with limitations; GMFCS III: Walking with a hand-held mobility device; GMFCS IV: Self-mobility using a wheelchair; GMFCS V: No independent mobility, being transported.[26]

accelerometer registering accelerations of one leg in the frontal and sagittal plane per time interval. The psychometric properties of the StepWatch™ have been shown to be good in children developing typically.[27-29] By sensitivity-adjusted calibration, performed as previously described, the StepWatch™ can also accurately record steps of one leg for children with CP.[8,9] The number of strides per day, the time (min) spent being inactive and at low stride rate (0-15 strides/min), time spent at moderate stride rate (16-30 strides/min), and time spent at high stride rate (31-60 strides/min) during a 24-hour day were used for analyses,[9,30] and will be further referred to as walking activity.

Additional measures

The participants' personal characteristics included GMFCS level, age, gender, and school type (regular school, or special school for children with a disability). The environmental characteristics comprised maternal educational level and assessment season. Maternal education was categorized as low (maximal a vocational degree) or high (minimal college degree or university degree). Assessment season was based on the date of measurement and determined as spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). For a subset of children with CP aged 7-9 years information was available on mobility capacity: gross motor capacity measured with the Gross Motor Function Measure-66 item sets,[31] and walking capacity measured with the one minute walk test.[32]

Procedure

After calibration, the StepWatch™ was programmed to record the number of strides per minute, so enabling registration of walking activity for a maximum of fifteen days. All children were instructed to wear the StepWatch™ during all waking hours, except for bathing and swimming, for at least seven days including the weekend. Children and parents were provided with verbal, written and visual information on how to wear the StepWatch™ around the ankle: The StepWatch™ was worn on the right leg, except for Dutch children with CP who wore it on the least affected leg. In both countries parents and/or children registered in a diary when the StepWatch™ was worn, enabling us to determine which days were representative for the child's walking activity.

A minimum of ten hours StepWatch™ wearing time was required for schooldays, and a minimum of eight hours for weekend days. Days with more than three hours of consecutive missing data were excluded. After this selection process, all 24-hour data was processed in R statistical software version 2.15.0 (The R foundation for Statistical Computing 2012, www.r-project.org) to calculate daily walking activity, and to label representative days as school day or weekend day using the date of measurement. With this information, mean walking activity was calculated for a typical schoolday, a weekend day, and for an average week day (scaled as 4/5 school day and 1/5 weekend day).

Data analysis

A priori sample size calculations indicated that 32 children in GMFCS I, 16 children in GMFCS II, and 19 children in GMFCS III were needed in each country to detect a clinically relevant difference of 1000 strides per day between countries.[33] Power was set at 70% and significance level at 5%, with standard deviations of 1605 strides, 1147 strides, and 1243 strides, for children in GMFCS I, II, and III respectively (based on previous data).[9]

Personal characteristics, environmental characteristics, and mobility capacity were tested for differences between countries with an independent t-test, Mann-Whitney U test, or Pearson Chi-square tests as appropriate.

To compare walking activity between countries, a multiple linear regression analysis was performed for children developing typically and for children in each GMFCS level separately, with walking activity as dependent variable, and country (0=The Netherlands, 1=United States) as independent variable. To test whether the differences in walking activity between children developing typically and children with CP differ across countries, we ran multiple regression models with a country-by-GMFCS interaction term in the model, in addition to the main effects. Variables with non-normally distributed residuals were logarithmically transformed prior to performing linear regression analyses. If residuals remained skewed a non-parametric Mann-Whitney U test was performed.

Gender (male or female), age (dichotomized as 7-9 years/10-12 years), and maternal education (low or high) were included as confounders in the linear regression models when they changed the regression coefficient of interest with more than 10%. All statistical procedures were performed with the Statistical Package for the Social Sciences 20.0 (IBM SPSS® Inc, Chicago, Illinois, USA), with significance set at $p<0.05$.

Results

Participants

Based on the above-mentioned criteria 134 children with spastic CP (Dutch: n=57, American: n=77) and 223 children developing typically (Dutch: n=40, American: n=183) were included in the study. The participant characteristics in Table 1 demonstrated no significant differences in the distribution of age and gender in samples from both countries. It can be observed that all American children in this sample went to regular schools, and the majority of Dutch children in GMFCS level II and III went to special schools for children with a disability. Maternal educational level was lower in the Netherlands ($p<0.001$) and assessment season was different between countries, particularly among children developing typically. Mobility capacity was not significantly different between both countries for the subset of children in GMFCS level III. Mobility capacity was significantly better in the Netherlands for children in GMFCS level I and II ($p<0.05$) among the subset of children aged 7-9 years.

Walking activity

Mean values for walking activity of children in each country and GMFCS level, as well as the adjusted differences (95% CI) in walking activity between children developing typically and children in GMFCS level I-III for each country are shown in Table 2 for schooldays, weekend days, and an average weekday. Figure 1 presents the mean walking activity for children developing typically and children in each GMFCS level on schooldays and weekend days.

Children developing typically showed no significant differences in walking activity between both countries for schooldays and weekend days. On weekend days, Dutch children classified as GMFCS level I took significantly less strides per day, spent more

Table 1. Characteristics of participants.

		n	NL	*n*	USA
Age, mean (SD)	Developing typically	40	9.92 (1.69)	183	9.96 (1.76)
	GMFCS Level I	33	10.48 1.62)	31	10.34 (1.59)
	GMFCS Level II	16	9.55 (1.26)	33	10.09 (1.69)
	GMFCS Level III	8	9.45 (1.27)	13	10.22 (1.56)
	Total	97		260	
Gender, *n* (%) male	Developing typically	40	20 (50.0)	183	92 (50.3)
	GMFCS Level I	33	22 (66.7)	31	16 (51.6)
	GMFCS Level II	16	10 (62.5)	33	21 (63.6)
	GMFCS Level III	8	4 (50.0)	13	4 (30.8)
School type, *n* (%) special school	Developing typically	40	-	183	-
	GMFCS Level I	33	15 (45.5)	31	0 (0)
	GMFCS Level II	16	12 (75.0)	33	0 (0)
	GMFCS Level III	8	6 (75.0)	13	0 (0)
Maternal education, *n* (%) low	Developing typically	39	19 (49)	181	31 (17)†
	GMFCS Level I	33	19 (58)	31	15 (48)
	GMFCS Level II	16	10 (63)	33	16 (49)
	GMFCS Level III	8	5 (63)	13	9 (69)
Season, *n* (%) spring/summer/autumn/winter					
	Developing typically	40	35 (87.5)/ 5 (12.5)/ 0 (0)/0 (0)	183	39 (21.3)/ 56 (30.6)/ 48 26.2)/ 40 (21.9)†
	GMFCS Level I	33	0 (0)/ 1 (3.0)/ 24 (72.7)/ 8 (24.2)	31	7 (22.6)/ 2 (6.5)/17 (54.8)/ 5 (16.1)*
	GMFCS Level II	16	0 (0)/ 1 (6.2)/ 11 (68.8)/ 4 (25.0)	33	9 (24.2)/ 8 (15.2)/ 8 (24.2)/ 13 (36.4)*
	GMFCS Level III	8	1 (12.5)/ 0 (0)/ 3 (37.5)/ 4 (50.0)	13	2 (15.4)/ 0 (0)/ 8 (61.5)/ 3 (23.1)
Gross motor capacity (score 0-100), median (min, max)‡					
	GMFCS level I	13	86.5 (79.1, 100.0)	10	86.5 (70.4, 92.1)
	GMFCS level II	9	73.6 (60.1, 92.1)	12	66.9 (56.4, 84.1)*
	GMFCS level III	6	53.5 (47.9, 65.0)	5	58.6 (45.0, 60.6)
Walking capacity (m), median (min, max)‡					
	GMFCS level I	13	97.0 (86.0, 117.0)	10	84.0 (70.0, 152.0)†
	GMFCS level II	9	83.0 (58.0, 98.0)	12	68.5 (52.0, 82.0)†
	GMFCS level III	6	54.5 (43.0, 68.0)	5	34.0 (12.0, 61.0)

NL=The Netherlands; USA=Pacific Northwest of the United States; GMFCS=Gross Motor Function Classification System; * $p<0.05$; † $p<0.01$; ‡ Only assessed in children with cerebral palsy aged 7-9 years.

Table 2. Walking activity (mean (SD), and for GMFCS level III (median (min, max)) of children developing typically and children with cerebral palsy in GMFCS level I-III in the Netherlands and the United States, and mean between group differences (95% CI) between countries.

		Developing typically			GMFCS I			GMFCS II			GMFCS III		
		NL	USA	Difference‡	NL	USA	Difference‡	NL	USA	Difference‡	NL	USA	Difference
		n=40	*n*=183	USA - NL	*n*=33	*n*=31	USA - NL	*n*=16	*n*=33	USA - NL	*n*=8	*n*=13	USA - NL
		Mean	*Mean*	*β*	*Mean*	*Mean*	*β*	*Mean*	*Mean*	*β*	*Median*	*Median*	r^{U}
		(SD)	*(SD)*	*(95%CI)*	*(SD)*	*(SD)*	*(95%CI)*	*(SD)*	*(SD)*	*(95%CI)*	*(min,max)*	*(min,max)*	
Strides per day	School days	8513	8264	-300[c]	5782	6450	926[a]	4852	5736	**1156[b]**	3341	1736	**-0.47***
		(1895)	(2376)	(-1142,542)	(1569)	(2563)	(-61,1912)	(1217)	(1701)	**(267,2044)***	(161,4786)	(307,6622)	
	Weekend days	8312	8238	-41[b,c]	4640	6603	**2211[a]**	4118	4613	715[b]	2098	1432	-0.22
		(2851)	(3426)	(-1265,1182)	(2167)	(3279)	**(863,3558)†**	(1677)	(2161)	(-511,1942)	(528,4482)	(226,8404)	
	Average week	8473	8259	-251[c]	5554	6481	**1183[a]**	4705	5511	**1076[b]**	3141	1605	**-0.46***
		(1826)	(2356)	(-1083,581)	(1554)	(2576)	**(193,2172)***	(1172)	(1660)	**(200,1935)***	(1395,4725)	(291,6978)	
Time at 0-15 strides/min (min) [§]	School days	1230	1238	8	1299	1285	-22[a]	1319	1302	**-25[b]**	1363	1406	**0.46***
		(46)	(59)	(-12,28)	(44)	(65)	(-47,4)	(36)	(46)	**(-50,-1)***	(1322,1412)	(1269,1440)	
	Weekend days	1232	1229	-5[c]	1328	1274	**-60[a]**	1341	1324	-23[b]	1398,	1406	0.21
		(75)	(89)	(-37,26)	(59)	(88)	**(-96,-23)†**	(52)	(66)	(-60,14)	(1320,1434)	(1202,1440)	
	Average week	1230	1236	6	1305	1283	**-29[a]**	1324	1306	**-25[b]**	1370	1411	**0.44***
		(44)	(60)	(-14,26)	(43)	(66)	**(-55,-3)***	(35)	(46)	**(-49,-0.3)***	(1324,1416)	(1256,1440)	
Time at 16-30 strides/min (min) [§]	School days	104	106	2[c]	84	85	4[a,b]	73	79	10[b]	56	24	**-0.47***
		(17)	(24)	(-6,10)	(27)	(24)	(-8,17)	(17)	(24)	(-3,22)	(22,74)	(0,122)	
	Weekend days	104	113	11[c]	67	94	**27**	66	76	OR=1.23[b,c]	24	19	-0.19
		(35)	(38)	(-3,25)	(31)	(43)	**(8,46)†**	(40)	(41)	(0.9,1.8)	(6,74)	(0,171)	
	Average week	104	107	4[c]	80	87	9[a]	72	79	11[b]	49	22	**-0.46***
		(17)	(24)	(-5,12)	(26)	(25)	(-4,21)	(18)	(25)	(-3,24)	(19,74)	(0,132)	
Time at 31-60 strides/min (min) [§]	School days	101	90	OR=0.88	54	66	OR=1.15[a]	46	56	**14[b]**	22	10	-0.35
		(38)	(38)	(0.8,1.0)	(19)	(41)	(0.9,1.5)	(19)	(23)	**(2,27)***	(6,46)	(0,48)	
	Weekend days	100	93	OR=0.81[c]	43	66	**28[a]**	32	38	OR=1.12[b]	20	4	-0.19
		(50)	(61)	(0.6,1.1)	(30)	(50)	**(8,48)†**	(26)	(28)	(0.6,2.1)	(1,47)	(0,63)	
	Average week	101	91	OR=0.88	52	66	**18[a]**	43	52	13[b]	20	11	-0.36
		(37)	(39)	(0.8,1.0)	(19)	(41)	**(4,33)***	(18)	(22)	**(1,25)***	(5,45)	(0,51)	

NL=The Netherlands; USA=Pacific Northwest of the United States; *β*=mean between-group difference; OR=odds ratio for linear regression analyses with logarithmically transformed data; [U] Non-parametric Mann-Whitney U test; *r*= the non-parametric effect size calculated as Z/(√N); ‡ Adjusted for gender, age, and/or maternal educational level; [a] Adjusted for gender; [b] Adjusted for dichotomized age; [c] Adjusted for maternal educational level; [§]Time spent in each stride rate level was calculated over a 24-hour day, which equals 1440 minutes; Significant interactions are in bold text; * p<0.05; † p<0.01.

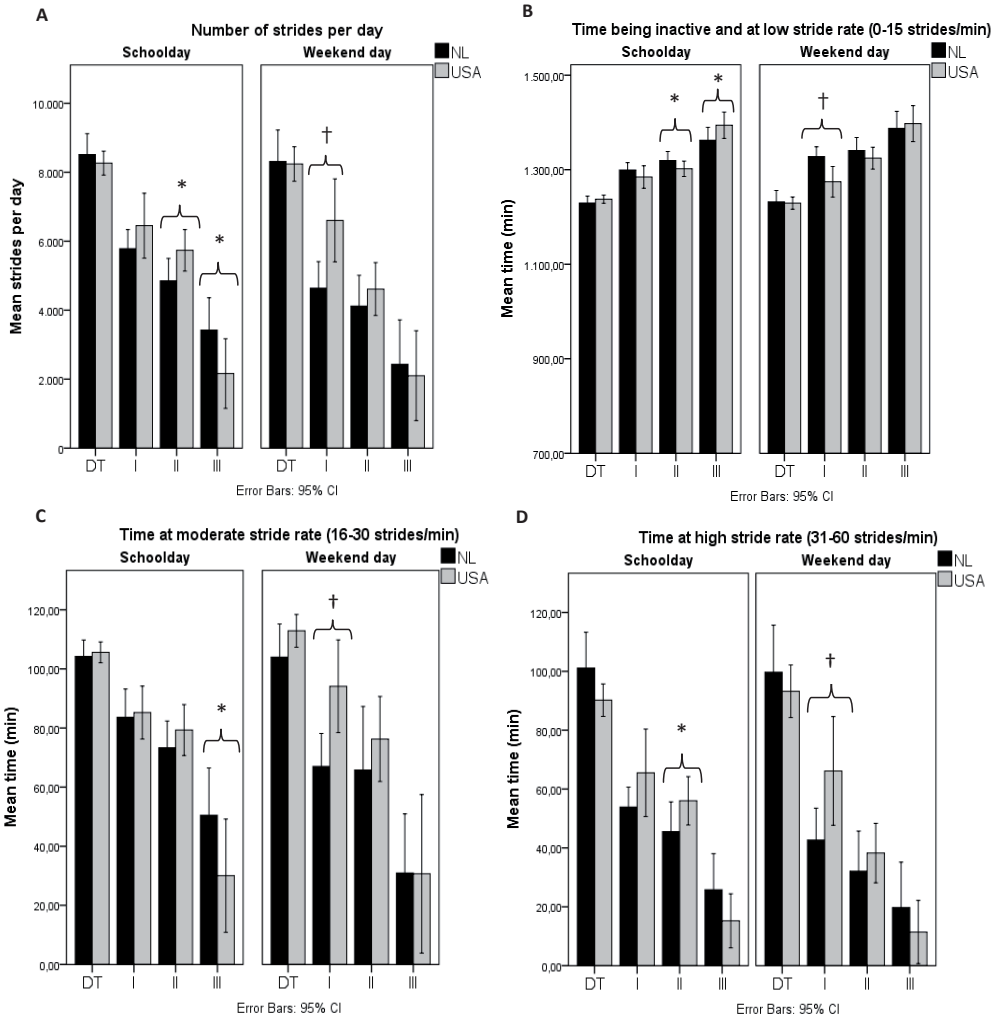

Figure 1. Means (95% CI) for walking activity on schooldays and weekend days among children developing typically, and children in GMFCS levels I-III. Means of children in each GMFCS level are compared between the Netherlands (NL) and the United States (USA): (A) Strides per day, (B) Time spent being inactive and at low stride rate (0-15 strides/minute), (C) Time spent at moderate stride rate (16-30 strides/minute), (D) Time spent at high stride rate (31-60 strides/minute); * $p<0.05$, and † $p<0.01$ represent significantly different walking activity between countries within each category.

time being inactive and at low stride rate, and spent less time at moderate and high stride rates than children in the United States, while walking activity of children in the other GMFCS levels did not differ between countries. On schooldays, there were no differences in walking activity between countries for children with GMFCS I. Dutch children with GMFCS level II were less active than children in the United States on schooldays (except for time spent at moderate stride rates), whereas children with

GMFCS level III took more strides, spent less time being inactive and at low stride rate, and more time at moderate stride rate than American children with GMFCS level III. The above described differences between countries for walking activity on either schooldays or weekend days were also found for an average weekday, except for time at moderate stride rate on an average weekday in children in GMFCS level I.

The results for the country-by-GMFCS interaction terms for each walking activity outcome are displayed for each GMFCS level in Table 3. Walking activity data of children in GMFCS III were not normally distributed. Therefore, walking activity of children in GMFCS level III was expressed as percentage of the mean walking activity of children developing typically in each country, and then compared between countries with a Mann-Whitney U test.

Table 3. Comparing walking activity of children with cerebral palsy in each GMFCS level between countries, with children developing typically in each country as reference group.

		Interaction country*GMFCS I *ß (95% CI)‡*	Interaction country*GMFCS II *ß (95% CI)‡*	Interaction country*GMFCS III *r* [U]
Strides per day	School days	1114[a] (-190 to 2419)	1133 (-379 to 2645)	**-0.47***
	Weekend days	**2288[a] (415 to 4162)***	569 (-1602 to 2741)	-0.24
	Average weekdays	**1349[a] (65 to 2634)***	1020 (-472 to 2512)	**-0.46***
Time at 0-15 strides/min (min)[§]	School day	-28 (-61 to 4.4)	-26 (-63 to 12)	0.38
	Weekend days	**-57[a] (-106 to 7.9)***	-14 (-71 to 44)	0.28
	Average weekdays	**-34[a] (-66 to 1.4)***	-23 (-61 to 15)	0.41
Time at 16-30 strides/min (min)[§]	School day	1.3[a] (-13 to 15)	4.6 (-11 to 20)	**-0.49***
	Weekend days	16[c] (-7.2 to 38)	1.6 (-25 to 28)	-0.21
	Average weekdays	2.6[c] (-12 to 17)	4.0 (-12 to 20)	**-0.46***
Time at 31-60 strides/min (min)[§]	School days	OR=1.27[a] (0.99,1.63)	**OR=1.39 (1.04,1.87)***	-0.32
	Weekend Days	**OR=2.01[a] (1.3,3.2)†**	OR=1.21 (0.7,2.1)	-0.17
	Average weekdays	**OR=1.34[a] (1.04,1.73)***	20 (-5.2 to 44)	-0.32

‡Adjusted for gender, age, and/or maternal educational level; [a] Adjusted for gender; [b] Adjusted for dichotomized age; [c] Adjusted for maternal educational level; [§]Time spent in each stride rate level was calculated over a 24-hour day, which equals 1440 minutes; OR=odds ratio for linear regression analyses with logarithmically transformed data; [U] Non-parametric Mann-Whitney U test to test the differences in percentage walking activity in GMFCS level III with respect to children developing typically; *r*=the non-parametric effect size calculated as Z/(√N); Significant interactions are in bold text; *p<0.05; [†] p<0.01.

On weekend days, the interaction for country and GMFCS level I was significant for the number of strides per day, time spent being inactive and at low stride rate, and time spent at high stride rate (but not for time spent at moderate stride rate), demonstrating a larger discrepancy in the Netherlands between children in GMFCS level I and children developing typically. The differences in walking activity between children developing typically and children in GMFCS level II or GMFCS level III were not different between countries on weekend days. On schooldays, the interaction for country and GMFCS level I was not significant. A larger discrepancy in walking activity between children developing typically and children in GMFCS level II, and a smaller discrepancy between children developing typically and children in GMFCS level III was found in the Netherlands compared to the United States. The above described significant country-by-GMFCS interaction terms on either schooldays or weekend days were also found for an average weekday, except for time at high stride rate on an average weekday in children in GMFCS level II.

Discussion

The aim of the study was to compare walking activity of children with CP who walk independently without (GMFCS level I and II) or with aids (GMFCS level III) and walking activity of children developing typically between the Netherlands and the Pacific Northwest of the United States. The hypothesis that children with CP, like children developing typically, would be more active in the Netherlands than in the United States was not confirmed, except in children with CP classified as GMFCS level III. Children developing typically showed no different walking activity in both countries, whereas contrary to our hypothesis children classified as GMFCS level I and II in the Netherlands generally demonstrated less walking activity than those in the United States. This is the first study comparing objectively assessed walking activity of children with physical disabilities between countries. In addition, no previous studies among children developing typically were identified that compared activity-monitor assessed walking activity between the Netherlands and the United States, while focusing on both schooldays and weekend days. The thorough study design with data in both countries collected and processed in the same way, and the use of the Gross Motor Function Classification System for the categorization of children with CP regarding walking in

daily life are important strengths of the study.

The lack of differences between countries for walking activity of children developing typically was contrary to our expectations, since a previous review has demonstrated that girls and boys who are developing typically take about 2375 and 2389 steps per day (equaling 1188-1195 strides per day) more in Europe than in the United States and Canada.[2] Possibly, these contrasting results are caused by the origin of our American sample of children from the Pacific Northwest, which involves some of the most active regions of the United States.[34] Thereby, the results from the review might not be representative for the Netherlands, since no Dutch studies were included in the review, and between-country differences in activity levels have been shown to exist within Europe.[3] Another explanation for the discrepancy with the literature might be due to the different monitoring devices used, since the previous studies used waist mounted pedometers (primarily the Digiwalker), whereas we used the ankle-worn StepWatch™ activity monitor. Nonetheless, we do not expect that these differences have substantially influenced our results, since both instruments were designed to record the number of steps or strides during walking.[27-29,35]

Despite no significant differences in walking activity between Dutch and American children developing typically, Dutch children in GMFCS level I and II demonstrated less walking activity, while Dutch children in GMFCS level III demonstrated more walking activity than their American counterparts, also when differences with typically developing children were considered. This suggests that environmental and cultural differences between countries may play a different role among children with CP than among children developing typically. Perhaps, the different school systems in both countries account for the differences in walking activity, since 75% of the Dutch children in GMFCS level II and III in our sample went to special schools for children with a disability, whereas the United States have a federally mandated policy of integration of children within the regular schools in the local area. However, previous work among children with CP did not demonstrate an association between school type (regular versus special schools) and walking activity within the Netherlands,[9] suggesting that between-country differences in school environment are responsible for the differences in walking activity

between countries among children with CP. Considering the common opinion that the United States is more widespread, American regular school complexes may include larger number of students, and are therefore bigger and may provide more walking activity for children in GMFCS level I and II, relative to the Dutch group. In contrast, the smaller Dutch schools may enable children in GMFCS level III to walk independently with a walking aid during school hours, whereas the supposed large distances in American regular school complexes and possible different opinions of professionals about the use of walking aids may result in more frequent use of wheelchairs during school hours. There were no studies to compare our between-country differences in walking activity of children with CP with. However, between European countries, variations in the difficulty of participation in daily activities have been reported among children with CP,[36] as well as variations in transport, social support, attitudes, and the access to the physical environment.[37] Colver et al. have demonstrated that less difficulty with mobility-related participation was associated with better transport and better access to the community environment, whereas participation in recreation was associated with better transport and better attitudes of family and friends.[38] Similar environmental and cultural factors for participation in physical activity were identified in a Dutch qualitative study in children with CP and their parents in the Netherlands, which also indicated that most attitudinal barriers had to do with social acceptance.[39] Perhaps, the discrepancy in walking activity between Dutch and American children with CP is explained by between-country differences in transport options, access to the school environment, and the social acceptance of children with a disability. However, since these environmental factors were not assessed in this study, further research is required to determine which factors can explain the reported differences.

It is possible that the lower activity levels of Dutch children in GMFCS level I and II are a result of more children with more severe CP being included in the Netherlands than in the United States. This seems unlikely though, since mobility capacity was comparable or better in a subset of Dutch children with CP aged 7-9 years. Another explanation for the lower walking activity levels of Dutch children in GMFCS level I and II might be the exclusion of highly active children in The Netherlands (5%),[40] which possibly resulted in an underestimation of walking activity among Dutch children with CP. However, similar

exclusion criterion were used for the Dutch children developing typically, justifying the comparison of the differences in walking activity between children with CP and children developing typically between countries. This even resulted in a larger discrepancy in walking activity between children with and without CP in the Netherlands compared to the United States, providing confidence in our results.

Children with CP in the Netherlands demonstrated less walking activity on weekend days, compared to schooldays, while walking activity was the same, or more, on weekend days in the United States. This pattern was not observed in children developing typically. An explanation may be a different attitude of the American population towards children with disability participating in the community, as illustrated by the integration of American children with CP in regular schools. This is supported by Verschuren et al. who have reported that social acceptance is a frequently mentioned barrier for participation in physical activity among Dutch children with CP and their parents.[39] Possibly, there are between-country differences in attitudes regarding children with CP participating in weekend day activities with peers who are developing typically, such as going to a sports club. Previous work among Dutch children with CP has shown that walking activity on weekend days is associated with sports club participation,[9] supporting that sports club participation is important. However, environmental factors, such as attitude, social acceptance, and sports club participation were not assessed in this study. Information on the nature of the walking activity during weekend days, as well as information about between-country attitudes towards the inclusion of children with CP in weekend-day activities may be helpful to clarify the discrepancies in the different walking activity levels on schooldays and weekend days between countries, and should be subject for further research.

The difference in walking activity of children with CP between countries seems to be mainly caused by time spent at high stride rates, since particularly this outcome showed significant differences when walking activity of children with CP was compared to children developing typically. In contrast, for children in GMFCS level III time at moderate stride rate was discriminative between countries. Possibly, the lower peak stride rates in these children are responsible for that, as supported by previous work

showing that children in GMFCS level III rarely reach stride rates higher than 30 strides per minute, while children in GMFCS level I and II easily do.[28] It should be noted that moderate and high stride rate levels do not seem to reflect moderate and high exercise intensity of all activities among children developing typically, or children with CP, since average heart rate reserve levels over these stride rate zones showed lower exercise intensities.[41] However, increasing stride rate has been shown to be associated with an increase in heart rate in children developing typically[30] and children with CP,[41] supporting that more strides per minute reflect more intense activities.[30,41] McDonald et al. have previously discussed the interpretation of the different stride rate levels, and suggested that low stride rate reflects intermittent steps taken during for example class time, moderate stride rate reflects intermittent walking, and high stride rate reflects continuous walking or running for short periods of time.[30] This may imply that Dutch children in GMFCS level I and II have more room to improve high stride rate walking activity, possibly by means of sports club participation or more community walking. Furthermore, American children in GMFCS level III seem to have more room to improve time at moderate strides rates, possibly by increasing the amount of short moments of walking by reducing time being inactive.

Limitations should be noted in the interpretation of these results. First, the Pacific Northwest of the United States is known to be among the most active parts of the United States,[34] limiting the generalizability of these findings to children in other parts of the United States. Nevertheless, because walking activity levels of children developing typically were not significantly different in these two regions (Pacific Northwest and the Netherlands), the discrepancies between countries for walking activity of children with CP offer more valuable information. A second limitation was that there was no equal distribution of walking activity data collection across seasons in both countries, particularly among the children developing typically, since none of these Dutch children were assessed during autumn and winter. Since previous work has not indicated clear influence of season on walking activity in the United States,[42] we suggest that the comparison between countries for children developing typically has not substantially been influenced by season. This was confirmed in a subgroup analyses comparing walking activity of Dutch and American children only assessed in autumn and winter,

which provided similar results. The third limitation is that fewer children with CP in GMFCS level II and III were included in the Netherlands than in the United States, possibly reducing the power of the study. However, post-hoc power analyses revealed an acceptable power of 74% for children in GMFCS level II (using a difference of 1076 strides, and standard deviations of 1172 and 1660 strides for the Netherlands and the United States, respectively). In addition, the significant difference between countries of more than 1000 strides per day among children in GMFCS level I, and II is suggested to be clinically relevant, providing confidence in the results and the conclusions.[33] Nevertheless, the small number of children in GMFCS level III included advocates for future research focusing on this group.

In conclusion, the walking activity of Dutch and American children developing typically was not different, but discrepancies between countries were found for walking activity of children with CP. This suggests that environmental between-country differences affect walking activity differently in children with CP. Dutch children with CP with no or little walking limitations seem to have opportunities for improving their walking activity by spending more time at the higher stride rates, whereas American children that use a walking aid may be able to improve their walking activity with more intermittent walking by reducing their time being inactive. Future research should examine which specific environmental factors should be addressed to improve walking activity of children with CP in both countries.

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