Research Report

Physical Activity Benefits of Learning to Ride a Two-Wheel Bicycle for Children With Down Syndrome: A Randomized Trial

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Background. People with Down syndrome (DS) display consistent patterns of physical inactivity. If these sedentary behaviors continue over extended periods of time, there will be negative health consequences.

Objective. The objective of this study was to investigate the physical activity and health-related outcomes of teaching children with DS to ride a 2-wheel bicycle.

Design. This study was a randomized intervention in which the control group waited 1 year to receive the intervention.

Setting. This intervention study was conducted in a community setting.

Participants. The participants were children who were 8 to 15 years of age and who had been diagnosed with DS.

Intervention. The participants were randomly assigned to an experimental group (bicycle intervention) or a control group (no intervention).

Measurements. Measurements were obtained in the month before the intervention (preintervention), at 7 weeks after the intervention, and at 12 months after the preintervention measurement for all participants.

Results. The results indicated no group differences at the preintervention session. Fifty-six percent of the participants in the experimental group successfully learned to ride a 2-wheel bicycle during the 5-day intervention. Analysis showed that participants who learned to ride spent significantly less time in sedentary activity at 12 months after the preintervention measurement and more time in moderate to vigorous physical activity than participants in the control group. Body fat appeared to be positively influenced over time in participants who learned to ride.

Limitations. It is unknown how frequently the children in the experimental group rode their bicycles after the intervention.

Conclusions. Most children who are 8 to 15 years of age and who have been diagnosed with DS can learn to ride a 2-wheel bicycle. Learning to ride can reduce time spent in sedentary activity and increase time spent in moderate to vigorous physical activity, which may influence the health and functioning of these children.

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Recent research has shown that engaging in physical activity is a primary avenue of prevention and intervention for combating obesity in all populations.[1] Physical inactivity and obesity also are growing problems in people with intellectual disabilities.[2–6] People with disabilities are less likely to be active than the general population, resulting in an increased strain on families and the health care system.[3,7,8] The physical activity of people with disabilities has been identified as a health priority by Cooper et al[9] as well as in the Surgeon General's report on improving the health of people with mental retardation.[3] These reports recommended that professionals develop methods to promote physical activity and reduce sedentary behaviors in people with disabilities.[2,3]

Down syndrome (DS) is a common genetic disorder that is identified before or soon after birth and that carries the certainty of developmental delays. In the United States, DS occurs approximately 1.36 times in every 1,000 live births.[10] Trisomy 21 is the most common cause; the extra copy of chromosome 21 results in gene overexpression. This genotype is present in approximately 95% of people with DS. The gene overexpression leads to a highly complex phenotype in which both physiological and cognitive developments are significantly altered.[11] Children with DS also experience significant delays in the onset of early motor milestones and display qualitative differences in movement patterns in comparison with children who show typical development (TD).[12–18] Additionally, children with DS have higher rates of overweight and obesity.[12,19]

Research on physical activity and its relationship to health in children with DS is extremely limited. One study[20] examined the physical activity patterns of 30 sibling pairs (children who had DS and a sibling who had TD and was closest in age) through parent report. The results indicated that parents perceived their children with DS to be less physically active than their siblings with TD.[20] Another study[21] investigated the physical activity levels of children with DS (mean age=7.1 years) and siblings with TD through the use of accelerometers. The results indicated that over a 7-day period, the average length of a bout of vigorous physical activity was significantly shorter in the children with DS.[21]

Most children with DS eventually learn a basic repertoire of motor skills; however, they seem to fall further behind their peers as they age. One culturally normative skill that often is never learned is riding a 2-wheel bicycle.[12,18,22] Bicycle riding in childhood provides many opportunities for engaging in physical activity as well as extended opportunities for social interactions with family members, peers, and community members. Menear[22] found that parents valued bicycle riding as a skill that could increase opportunities for their children to participate in the community and interact with peers.

Recent research has clearly demonstrated the negative impact of sedentary behaviors on health.[23–25] Children and adolescents with DS are less active than their peers with TD.[20–22,26] However, despite the evidence regarding the passive nature of children with DS,[26] little research has been conducted on designing and testing interventions to decrease sedentary behaviors in people with DS and increase the time that they spend in physical activity.[27]

The Bottom Line

What do we already know about this topic?

Children and youth with Down syndrome display a very stable pattern of physical inactivity, which gets worse with age.

What new information does this study offer?

Less than 10% of children with Down syndrome who are 8 to 15 years of age can ride a 2-wheel bicycle. This intervention study demonstrated, over a 5-day period, that a majority of children with Down syndrome can learn to ride a 2-wheel bike if given intensive, individualized instruction. Those children who learned to ride demonstrated a significant decrease in time spent in sedentary activity 12 months after training and a reduction in subcutaneous fat.

If you're a patient or caregiver, what might these findings mean for you?

If you or someone you care for has Down syndrome, your physical therapist may advise you to seek out a bicycle training program such as that conducted by the Lose the Training Wheels organization and, after you have learned, to ride your bike as often as you can. Your physical therapist also may encourage you to learn other activities to increase your daily physical activity.

The aim of our randomized intervention study was to test the hypothesis that increasing the physical activity and motor skill repertoire of children with DS by one functional, culturally normative activity valued by most families could have a positive impact on patterns of physical activity associated with health and functioning. Our expectation was that with available training technology and individualization of training, we could teach most children with DS to ride a 2-wheel bicycle and, as a result, that those who learned to ride would significantly decrease the time spent in sedentary activity (SED) and increase the time spent in moderate to vigorous activity (MVPA). We also anticipated that a decrease in time spent in SED and an increase in time spent in MVPA might decrease body fat or at least prevent it from being increased over a 12-month follow-up period. This is the first intervention study founded on the principles of dynamic systems theory[28] in an effort to change patterns of physical inactivity in children. We are treating the motor and physical skill repertoire in children with DS as a potential control parameter (ie, an inability to ride a 2-wheel bicycle). Our intervention is designed to help children scale up their repertoire with a highly valued activity (riding a 2-wheel bicycle) and, as a result, shift the children away from more sedentary behaviors.

Method

Written informed consent from parents and assent from children were obtained. A total of 72 children who had DS and who were 8 and 15 years of age were enrolled and randomly assigned to either an experimental (EXP) group (bicycle intervention) or a control (CON) group (no intervention) (the CON group waited 1 year to receive the intervention). Participants were recruited through contact with and presentations to 5 large organizations for parents of children with DS in Michigan, Ohio, and northern Indiana. According to parent report during recruitment and child report during initial data collection, none of the participants could ride a 2-wheel bicycle at entry into the study. Most parents claimed that they had been trying for years to teach their children how to ride a 2-wheel bicycle and had basically given up trying.

Figure 1 shows the flow of participants (N=81) through the study. Children were excluded from the study if they had any medical conditions (eg, uncontrolled seizures) that did not allow physical exertion at a moderate level or if they exhibited severe behavioral issues during screening or measurements that prohibited them from being able to benefit from instruction within a community setting. Eleven children were not included in the final analysis because of parent withdrawal or attrition at follow-up. Of the 61 remaining children, 34 remained in the EXP group and 27 remained in the CON group.

For all participants, regardless of group, measurements were obtained in the month before the intervention (preintervention), at 7 weeks after the intervention (post-1), and at 1 year after the preintervention measurement (post-2). Measurements included leg strength, standing on one leg for balance, height, weight, skinfolds, and physical activity. These measurements were selected primarily because they represented performance and health-related areas that could be affected by participation in physical activity. This selection appears to conform to the concepts included in the *International Classification of Functioning, Disability and Health* (ICF) model.[29] We hypothesized that participation in and acquisition of the skill of bicycle riding by children with DS could reduce SED, increase leg strength, and reduce body fat.

Leg Strength

Isometric knee extensor muscle strength was assessed with a manual muscle tester (MMT) (Lafayette Instrument Co, Lafayette, Indiana). The participant was seated on a table with the knee at 120 degrees, as measured with a goniometer. The MMT was placed on the distal anterior shank approximately 7.6 cm (3 in) above the ankle. The participant was encouraged to provide maximal force against the MMT for 5 seconds; peak force was recorded in kilograms. Three trials were performed, and the peak value was used for each leg. Isometric knee flexor muscle strength was assessed with the participant in a prone position on the table with the knee flexed to 20 degrees off the table. The MMT was placed on the lower portion of the posterior side of the leg approximately 7.6 cm above the ankle. Three trials were performed, and the peak value was used for each leg. Research staff received training with the MMT and had to demonstrate consistency across several trials and with 2 testers experienced in the professional use of the MMT. The research coordinator observed the 2 testers during the formal testing to ensure that consistent procedures were being implemented.

Standing Balance

Standing balance was assessed by asking the participant to place the hands on the hips and stand on one foot. Each participant was allowed to continue until 60 seconds was reached or the standing foot was displaced, the hands were removed from the hips, or the raised leg touched the floor. Time was measured to the nearest tenth of a second. Three trials were repeated for each leg, and the peak value was used. The research coordinator arbitrarily observed the testing station to

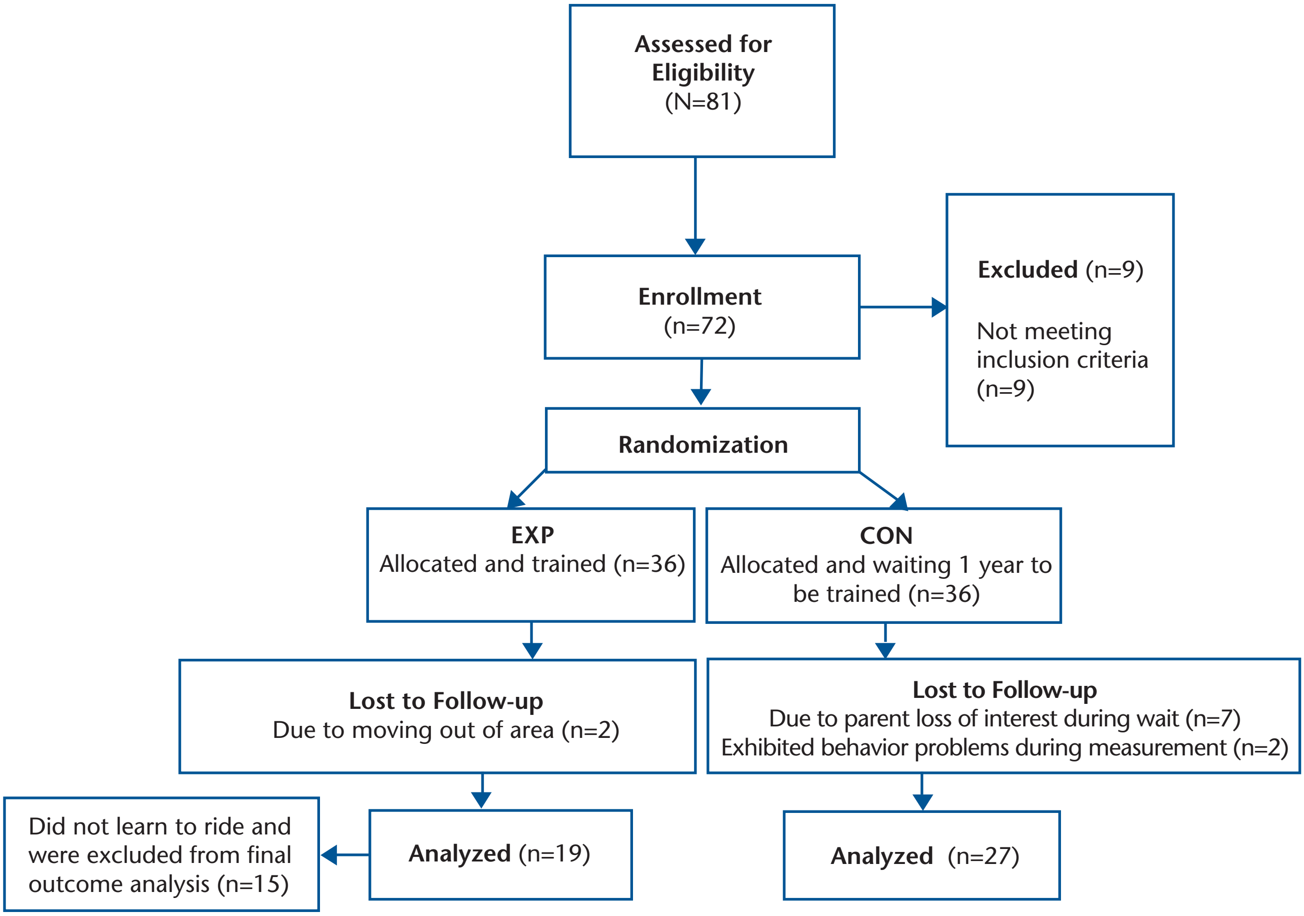

Figure 1.
Flow of participants through the study. EXP=group that received bicycle training, CON=group that waited to receive bicycle training.

ensure that the testers were scoring the performances consistently. In the event that the scores recorded by the coordinator and the tester differed by 0.5 second or more, the trial was repeated.

Height, Weight, and Skinfolds

Height and weight were measured with the child wearing no shoes. Height was measured to the nearest tenth of a centimeter with a portable stadiometer (SECA S-214) (Seca Corp, Hanover, Maryland). Weight was measured to the nearest tenth of a kilogram (Health O Meter H-349KL digital scale) (Pelstar LLC, Alsip, Illinois). Skinfold measurements were taken by a physician who had many years of experience with skinfold measurements involving children. Skinfold measurements were taken at the triceps muscle and calf with Lange skinfold calipers (Beta Technology, Santa Cruz, California). The calipers were calibrated before each of the 3 measurement sessions. All measurements were taken on the right side of the body and to the nearest tenth of a millimeter in accordance with standardized procedures.[30] Two measurements were obtained at each site, and the average was used. A regression equation was used to calculate the percentage of body fat.

Physical Activity

Physical activity was assessed for 7 days with Actical accelerometers (Phillips Respironics Inc, Bend, Oregon). The Actical monitor was programmed to sample at intervals of 15 seconds. Participants and their parents were instructed on how to wear the monitor (placing it on the right hip just above the iliac crest with an elastic belt) and were told that children should wear the monitor for all activities except swimming, showering or bathing, and sleeping. They also were given a log to record times when the monitor was not worn. Because of the limited number of accelerometers available, each physical activity measurement was obtained as close as possible to the 3 measurement time points described above.

Figure 2.
Adapted bicycle.

Intervention

The bicycle training intervention was provided by the Lose the Training Wheels organization (Goddard, Kansas) and consisted of 5 consecutive days of individual instruction for 75 minutes per day. Five days of training is currently the only option provided by the Lose the Training Wheels organization (see Appendix for a description of the basic training manual). Trained staff with professional experience with children who had cognitive constraints and DS were used. The intervention was set up in a summer camp format in which the participants came into the training facility for 75 minutes and then returned home until the next day. Specially engineered adapted bicycles provided by the Lose the Training Wheels organization were used for the initial training (Fig. 2 shows an example of an adapted bicycle). The adapted bicycles were tailored throughout the training to the participants' individual needs on the basis of their level of riding skill. The adapted bicycles have a series of 8 roller wheels (Fig. 3). The roller wheels taper progressively from roller 1 to roller 8. The first and second roller wheels afford riders with many opportunities to pedal continuously without fear of falling and to learn to stop and place their feet firmly on the floor. The seventh and eighth roller wheels are the most tapered on the ends; by the time riders have advanced to these roller wheels, they have demonstrated good control of the adapted bicycle. The floor manager continuously observes each rider during the training session to determine when the rider is ready for a change in the roller wheel. To make this decision, the floor manager looks primarily at the speed of pedaling, whether riders are beginning to lean into a curve, and whether riders are beginning to relax the joints in their arms and begin to use the handle bars to turn and control the bicycle. Most riders begin the training by freezing the degrees of freedom in their arms (locking their arms) to better control the bicycle and because they anticipate falling. Once they succeed in continuous pedaling around the training facility for 10 minutes or more without falling, they begin to relax the joints in their arms. The adapted bicycle also has a handle attached to the rear for the trainer to use, when necessary, as a prompting system to facilitate continuous pedaling or leaning into turns or to stop the rider quickly to prevent a fall. The goal is to progress to a standard 2-wheel bicycle.

As the child's performance improved over the 5 days of training, he or she received training on bicycles that became progressively more similar to a standard 2-wheel bicycle with the training handle still attached. Parents were encouraged to bring the child's own bicycle to the training program by the last day to assist the child in making a successful transition to his or her own bicycle for riding at home. Participants were tested on the final day of the intervention to measure their success in riding independently on a 2-wheel bicycle for a minimum of 9 m (30 ft). Riders were positioned on their 2-wheel bicycles, and a distance of 9 m was marked in front of them. On the basis of the measurements taken on the final day, participants in the EXP group were classified as having learned to ride a 2-wheel bicycle (EXP-L group) or not having learned to ride a 2-wheel bicycle.

Figure 3.
Series of rollers for adapted bicycle.

Data Reduction

For the physical activity measurements, data were used if the participant wore the monitor for a minimum of 10 hours per day for a minimum of 4 days out of each of the 7-day monitoring periods. One of the 4 days also must have been a weekend day. These criteria have been established in the literature as suggested guidelines for including valid data points.[31] The data were reduced to assign the activity count per 15-second epoch into the following categories: SED and MVPA. We also summarized the data by calculating the average activity counts per minute (AVGMIN). We used the cutoff points (adjusted for 15-second epochs) outlined by Puyau et al[31] because they were established with Actical accelerometers in children who were in the same age range and had TD. At the time of data collection and reduction, no known regression equations had been developed for children with DS; thus, we used cutoff points established for children who were in the same age range but had TD.

Data Analysis

A mixed-model analysis was performed with SPSS version 18.0 (SPSS Inc, Chicago, Illinois). Performing a retrospective analysis, we defined the EXP group as including only participants who did learn to ride a 2-wheel bicycle (EXP-L group) to elucidate the effects of successfully learning to ride after the intervention (defined by riding independently a minimum of 9 m). We did not include in the final outcome analysis any participants in the EXP group who did not learn to ride. Therefore, 19 participants in the EXP-L group and 27 participants in the CON group were included in the outcome analysis. Sex and age at entry into the study were covariates, and group (EXP-L and CON) and time (preintervention, post-1, and post-2) were main effects in the model. The interactions of group and time also were examined to determine whether one group performed better than the other group over time. The dependent variables tested were knee flexion and extension strength in the right and left legs, body mass index (BMI), percentage of body fat, standing balance on the right and left legs, AVGMIN, and number of minutes per day spent in SED and MVPA. For the activity variables, we co-varied whether or not the days were weekend days or weekdays. The significance level was set at .05. *Post hoc* analysis was performed with Bonferroni corrections.

Role of the Funding Source

Partial funding for this research was provided by the National Down Syndrome Society, the Steelcase Foundation, the Lyle Foundation, and the Down Syndrome Association of Western Michigan. Doctoral students were funded in part by a leadership training grant (H325D070081) awarded to Dr Ulrich by the US Office of Special Education Programs, US Department of Education. The Lose the Training Wheels organization provided access to their fleet of adapted bicycles and monitored the bicycle training protocol.

Results

The average ages at entry into the study were 12.0 (SD=1.9) years for the CON group and 12.4 (SD=2.2) years for the EXP-L group. There were 11 boys and 16 girls in the CON group and 9 boys and 10 girls in the EXP-L group. The race or ethnicity breakdown of the convenience sample was as follows: 24 white, 2 African American, and 1 "other" in the CON group and 16 white, 1 Hispanic, and 2 "other" in the EXP-L group.

No significant group differences were found in any of the variables measured at preintervention. The results of the mixed-model analysis indicated a significant group × time interaction ($F_{2,85}$=3.71, *P*=.028) for BMI. *A post hoc* analysis showed that the CON group had a significant increase in BMI at post-2 relative to that at the baseline (*P*<.001). In addition, main effects of group were found for knee flexion in the right and left legs. The EXP-L group had significantly greater knee flexion in the right leg ($F=4.49_{1,38}$, *P*=.041) and left leg ($F=5.38_{1,38}$, *P*=.026) overall than the CON group. However, no significant group × time interactions were observed. The only other significant result was the main effect of the group × time interaction for the percentage of body fat ($F=3.17_{2,84}$, *P*=.047). A *post hoc* analysis showed that overall, the EXP-L group had significantly decreased percentages of body fat at post-1 and post-2 (*P*=.004 and *P*=.006, respectively). The raw data and *P* values for the main effect of the group × time interaction are shown in the Table.

For the physical activity data, significant group × time interactions were found for SED ($F=3.81_{2,611}$, *P*=.023), MVPA ($F=5.22_{2,622}$, *P*=.006), and AVGMIN ($F=5.55_{2,620}$, *P*=.004). There was no significant difference in total activity monitor wear time between the groups. The range of activity monitor wear times across groups and measurement sessions was 12.8 to 13.6 hours per day. A *post hoc* analysis of time spent in SED showed a significant decrease at post-1 (*P*=.001) and post-2 (*P*<.001) relative to preintervention for the EXP-L group. The EXP-L group also spent significantly less time in SED at post-1 (*P*=.035) and post-2 (*P*=.004) than the CON group (Fig. 4). A *post hoc* analysis showed the EXP-L group spent significantly more time in MVPA at post-2 than the CON group (*P*=.023). A *post hoc* analysis also showed that the CON group spent more time in MVPA at preintervention than at post-1 (*P*<.001) and post-2 (*P*=.004); meanwhile, the EXP-L group spent significantly more time in MVPA at post-2 than at post-1 (*P*=.009). A *post hoc* analysis showed that the EXP-L group had significantly higher AVGMIN than the CON group at both post-1 (*P*=.023) and post-2 (*P*=.004). For the CON group, AVGMIN significantly decreased from baseline to post-1 (*P*=.004) and baseline to post-2 (*P*=.039), whereas for the EXP-L group, AVGMIN significantly increased from baseline to post-2 (*P*=.018) (Fig. 5).

Discussion

In preparation for conducting the present intervention study, we surveyed 298 families who lived in Michigan, Ohio, and Indiana and who had a child with DS in the age range of 8 to 15 years; according to parent report, 9.7% of the children in this age range could ride a 2-wheel bicycle. The average age of this group was 12.5 years. These data support the view that learning to ride a 2-wheel bicycle is a challenging task for this population. The

Table.
Analysis of Outcome Variables by Group[a] and Time[b]

Variable	Preintervention			Post-1			Post-2			P^c
	$\bar{X}$ (SD)		Effect Size, Cohen *d*	$\bar{X}$ (SD)		Effect Size, Cohen *d*	$\bar{X}$ (SD)		Effect Size, Cohen d	
	EXP-L Group	CON Group		EXP-L Group	CON Group		EXP-L Group	CON Group		
Knee extension strength, right leg, kg	15.8 (10.1)	12.9 (6.6)	0.35	19.7 (9.8)	15.9 (5.4)	0.50	15.0 (4.0)	12.3 (4.5)	0.64	
Knee extension strength, left leg, kg	15.4 (10.3)	13.5 (6.3)	0.23	20.1 (10.2)	15.4 (5.9)	0.58	14.7 (4.0)	12.0 (4.9)	0.61	
Knee flexion strength, right leg, kg	13.6 (11.2)	11.1 (4.3)	0.32	17.5 (9.1)	12.6 (4.1)	0.74	15.0 (4.4)	12.0 (5.1)	0.63	
Knee flexion strength, left leg, kg	13.3 (8.3)	11.3 (4.7)	0.31	17.2 (11.2)	12.2 (4.4)	0.64	13.6 (4.0)	10.2 (4.4)	0.81	
Balance, right leg, s	4.7 (4.8)	3.9 (2.7)	0.21	7.0 (7.8)	5.1 (5.4)	0.24	7.3 (8.3)	4.5 (4.0)	0.45	
Balance, left leg, s	5.3 (4.9)	4.5 (6.8)	0.14	6.6 (5.7)	5.1 (6.1)	0.25	8.3 (8.8)	4.1 (3.3	0.69	
Body mass index, kg/m^2	24.3 (5.5)	23.0 (4.8)	0.25	24.3 (5.5)	23.3 (4.8)	0.19	24.6 (4.7)	24.3 (5.2)	0.06	.028
Percentage of body fat	36.7 (14.5)	32.1 (13.6)	0.33	31.5 (12.5)	28.2 (11.1)	0.28	30.5 (9.8)	29.5 (9.3)	0.10	.047
Time spent in sedentary activity, min	531.7 (101.1)	537.1 (104.7)	0.05	473.0 (155.5)	522.8 (141.8)	0.34	456.6 (139.1)	527.6 (139.1)	0.63	.023
Time spent in moderate to vigorous activity, min	39.2 (23.7)	46.9 (29.2)	0.29	36.5 (25.8)	34.8 (18.0)	0.08	48.7 (26.2)	39.7 (23.8)	0.36	.006
Average activity, counts/min	284.6 (124.8)	314.2 (154.0)	0.21	304.5 (140.6)	270.7 (112.0)	0.27	352.5 (134.2)	290.8 (132.8)	0.46	.004

[a] Experimental group, consisting of participants who learned to ride a 2-wheel bicycle (EXP-L group), and control group, consisting of participants who waited 1 year to receive the intervention (CON group).
[b] Before the intervention (preintervention), 7 weeks after the intervention (post-1), and 1 year after the preintervention measurement (post-2).
[c] For the group × time interaction effect.

results of the present study demonstrate that 56% of the total participants in the EXP group learned to ride a 2-wheel bicycle with 75 minutes of individualized training per day for 5 consecutive days. These results and those of other studies lend support for this method of training people with DS[32,33] to ride a bicycle. Many of the participants who had DS and who learned to ride are not necessarily prepared to ride their bicycles on busy city streets. Bicycle riding can be done for exercise and recreation in many locations, including parks, bicycle paths, large parking lots, local neighborhood sidewalks, and school playgrounds. Parents were encouraged to promote bicycle riding and continued practice in riding. At post-2, according to parent report, none of the participants in the CON group, who did not receive the bicycle training, could demonstrate the ability to ride a 2-wheel bicycle.

When all of the participants in the EXP and CON groups were compared, the physiological and motor measurements of leg strength, BMI, percentage of body fat, and one-leg balance were not significantly affected over the 1-year period after an intervention aimed at teaching children with DS to ride a 2-wheel bicycle. This finding should not be surprising given that 44% of the total participants in the EXP group did not learn to ride a 2-wheel bicycle independently within the 5-day intervention and, therefore, were functioning more like participants in the CON group. Because of this result, participants in the EXP group who did not learn to ride were excluded from any outcome analysis. Given the variability in cognitive development in people with DS, some of the participants who did not learn to ride may have simply needed more

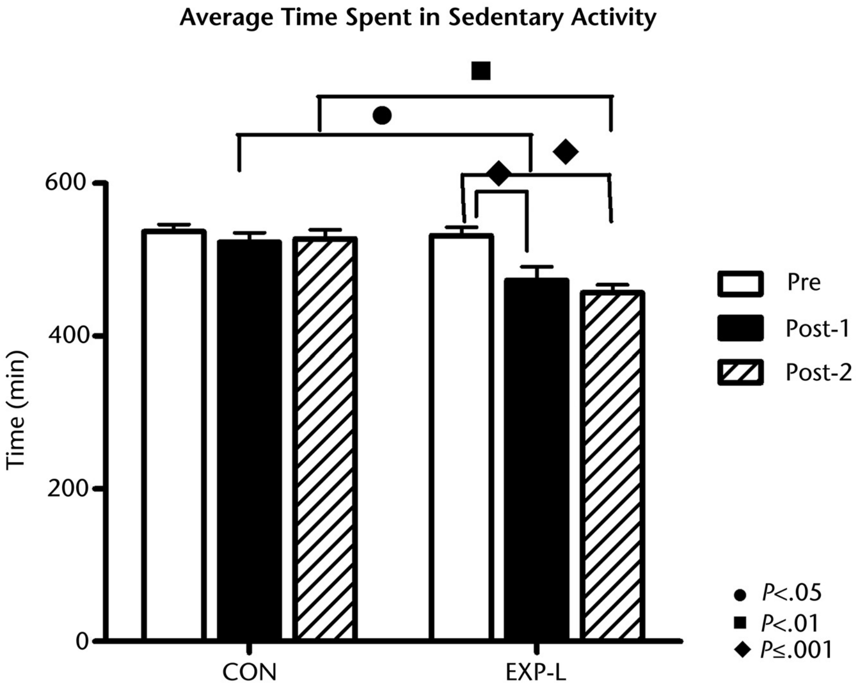

Figure 4.
Average time (minutes) spent in sedentary activity by participants in the experimental group who learned to ride a 2-wheel bicycle (EXP-L group) and participants in the control group (who waited 1 year to receive the intervention) (CON group) across measurements. Pre=before the intervention (preintervention), Post-1=7 weeks after the intervention, Post-2=1 year after the preintervention measurement.

days of practice and training. This conclusion is supported by the general observation that several riders in the EXP group were close to meeting the criterion of 9 m on the final day of the intervention but did not achieve it. In the future, this hypothesis could be tested by providing access to training bicycles for a longer period than the standard 5 days.

We observed that fear of falling appears to be a major constraint in teaching people with DS to ride a 2-wheel bicycle. This observation was based on the behavior of most of the participants while pedaling during day 1 or 2 of training and is supported by recent motor control research involving people who have DS and who have concluded that their major goal in movement is to move safely.[34] This fear can be a factor in why most children and youths with DS do not learn how to ride a 2-wheel bicycle. However, all participants in the EXP group made observable improvements in their ability to ride over the 5 days of the intervention. These improvements were frequently noted in comments made by parents during each day of training.

Analysis of data from the EXP-L group and the CON group showed a trend for both BMI and percentage of body fat to be potentially affected over the 1-year follow-up period. On the basis of effect size statistics (Table), the EXP-L group displayed higher BMIs and percentages of body fat at the preintervention measurement, but this difference disappeared over 12 months (post-2). This finding warrants additional research into whether learning to ride a bicycle may enhance physical health by improving body composition.

The most meaningful result of the present study appears to be that the EXP-L group reduced the average amount of time spent in SED per day by 75 minutes. With any standard of evaluation, this reduction in SED is amazing and, if continued, should have a positive impact on future health. The results also demonstrated that, compared with the CON group, the EXP-L group significantly increased the time spent in MVPA at post-2. This pattern was reflected in the AVGMIN variable. This difference cannot be explained by increased age, given that physical activity typically decreases with increased age.[35] Interestingly, the research staff received unsolicited communications from multiple parents whose children were in the EXP-L group, suggesting that the parents perceived that their children were less fearful and more motivated to try other physical and sports activities after overcoming their fear of falling and learning to ride a 2-wheel bicycle. These parental perceptions need to be validated in future research.

The improvement in physical activity levels could help explain the trend exhibited in percentage of body fat. Increased physical activity can contribute to decreased body mass, which was a trend found in the EXP-L group. It is not clear why time spent in MVPA decreased in the CON group during this time, although the literature on children with TD shows a decline in physical activity after the onset of puberty, so it is possible that this phenomenon is reflected in youths with DS as well.[36] However, this phenomenon would affect both the EXP-L group and the CON group equally. The decrease in time spent in MVPA by both groups at post-1 could have been a seasonal effect because post-1 measurements generally occurred in August and September, when outside temperatures during the day were high and schools were resuming classes. In summary, the physical activity results of the present study indicate that participating in an adapted bicycle training program has the potential to decrease time spent in SED and increase time spent in MVPA or at least stave off its decline with age—a factor that is especially important for the overall health of children with DS.

The results of the present study provide support for our hypothesis that increasing the physical activity skill repertoire with a functional, culturally normative activity valued by most families and children could have a positive impact on physical activity associated with health and functioning. Increasing time spent in MVPA by children and youths is a significant challenge faced by practitioners around the world,[35] and children with DS are less likely to engage in physical activity than their peers with TD.[20,21] The results of the present study demonstrate that learning how to ride a 2-wheel bicycle may increase or maintain time spent in MVPA by children with DS—a promising idea. Interestingly, a reduction in time spent in sedentary behaviors is emerging as the front line of action in promoting physical activity in children and youths. Therefore, the demonstration of a significant decline in time spent in sedentary behaviors in the present study is a major milestone in determining strategies for promoting physical activity and reducing sedentary behaviors in children and youths with DS. Additional research is needed to determine whether the effects are maintained over longer periods of time. The present study appears to serve as an example of an intervention founded on the concepts included in the ICF model. Acquiring skills in other physical activities, such as dance, swimming, and martial arts, also should improve participation, functioning, and health-related outcomes. Future physical activity interventions also must involve parents to help maximize the frequency of riding for children with DS and to evaluate how parental support for physical activity mediates the frequency of riding and important health-related and functional outcomes.

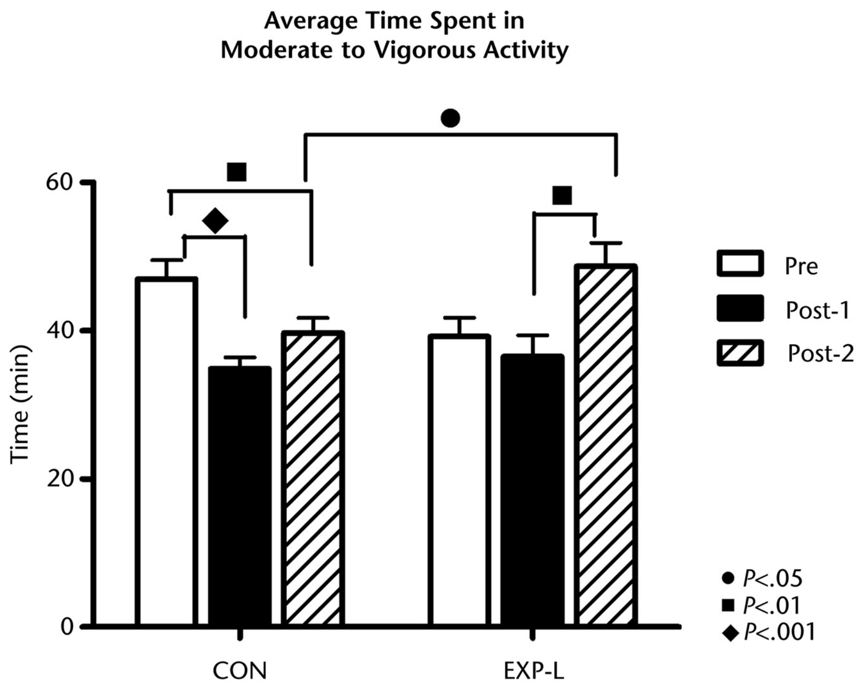

Figure 5.
Average time (minutes) spent in moderate to vigorous activity by participants in the experimental group who learned to ride a 2-wheel bicycle (EXP-L group) and participants in the control group (who waited 1 year to receive the intervention) (CON group) across measurements. Pre=before the intervention (preintervention), Post-1=7 weeks after the intervention, Post-2=1 year after the preintervention measurement.

Limitations

This training study had several limitations. The first limitation was that not all of the participants in the EXP group learned to ride a 2-wheel bicycle and therefore were not included in the final outcome analysis; this factor reduced the statistical power. Second, some of the parents whose children were randomly assigned to the CON group decided that they did not want to wait 1 year for their children to receive training and dropped out of the study. In future research, families assigned to the CON group should be paid for waiting; the compensation could be used to access an alternative intervention (not bicycle training) to help meet the needs of their children while they wait to receive the bicycle training intervention. The third limitation was the lack of a follow-up measure of the frequency of riding by the participants over the 12-month follow-up period. This measure could have helped us explain why some participants who learned to ride displayed more or fewer benefits in the long term. The final limitation relates to the method of wearing the Actical physical activity monitor. We elected to follow the standard protocol of wearing the monitor on the right hip. In retrospect, wearing the monitor on the hip most likely meant that much of the increased physical activity resulting from bicycle riding was missed because the participants were sitting down (on the bicycle seat) while they rode. However, the Actical is the accelerometer of choice for measuring physical activity over an entire day, even though it is not as accurate at capturing activities such as biking and swimming (because of water).[37] To capture actual differences in riding behaviors, a second accelerometer could be placed on the ankle to monitor changes in leg activity due to riding; however, much more research is needed to validate this procedure.

On the basis of the results of our randomized intervention study, it appears that the principles of dynamic systems theory[28] can serve as a foundation for changing patterns of physical inactivity in children with DS and children without DS. Future research is needed to identify other potential control parameters that are modifiable with therapy and training in an effort to shift children away from stable patterns of physical inactivity. We have provided support for increasing the skill repertoire, but other factors also must be considered and tested; these factors include leg strength, endurance, confidence, and psychosocial factors that may improve with the increased socialization that occurs with increased participation in physical activities within the community.

Conclusion

The majority of children who have DS and who are older than 8 years of age can learn to ride a 2-wheel bicycle given appropriate individualized training. More clinical and educational settings should make an effort to teach people with DS to ride a 2-wheel bicycle, to develop strategies for monitoring and reinforcing the frequency of riding, and to distribute information to parents on locations within their community to ride. Therapists also should encourage organizations for parents of children with DS (especially the DADs [Dads Appreciating Down Syndrome] group) to organize bicycle riding groups and to encourage riders to train and enter the bicycle riding events in the Special Olympics. The Special Olympics will increase the availability of riding events only if more participants learn to ride. Therapists should provide parents with methods for increasing their child's leg strength before enrolling in a bicycle training program. Participants who did not learn to ride frequently spent more time off the bicycle during the intervention sessions and stated that their legs were too tired to continue. Leg fatigue may have been present, but low levels of motivation were observed in many of the participants who were 8 or 9 years of age and who used leg fatigue as an excuse to get off the bicycle. Participants who spent most of the 75 minutes available for training on the bicycle practicing generally learned to ride in 5 days.

Dr Ulrich, Dr Lloyd, Mr Tiernan, and Dr Hornyak provided concept/idea/research design. All authors provided writing and data collection. Ms Burghardt provided data analysis. Dr Ulrich and Ms Burghardt provided project management. Dr Ulrich provided fund procurement. Dr Lloyd provided consultation (including review of manuscript before submission).

All methods used in this study were approved by the University of Michigan Institutional Review Board.

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Appendix.

Bicycle Training Manual[a]

This is a manual addressing the critical training guidelines used by researchers during 2-wheel bicycle interventions for youth with Down syndrome and autism spectrum disorder. The challenge of learning to ride a standard 2-wheel bicycle is to attain effective internal feedback needed for balance while riding a bicycle that initially is perceived to be unpredictable and unstable.[b] This sense of instability activates ineffective defense responses. These same responses are reinforced when using training wheels and lead to the acquisition of a counterproductive motor plan. In turn, when the training wheels are removed, the rider's response to the bicycle's action is opposite of the motor plan that is necessary to maintain control of the bicycle. The method developed in this manual is designed to teach individuals the correct motor plan for riding a 2-wheel bicycle through a series of bicycle adaptations and individualized training, while at the same time reducing their fear of falling. In addition, it is recognized that similarities exist in patterns of learning among individuals with and without disabilities; however, individuals with disabilities may require additional time and specialized teaching strategies to have success.[b] This training incorporates innovative teaching techniques and specialized equipment designed to facilitate 2-wheel bicycle riding success for individuals with disabilities.[b]

Research Study Information

Training Details

1. One or 2 months prior to intervention, measurements of physical activity using Actical physical activity monitors are recorded.
2. One or 2 days prior to intervention, measurements encompassing areas of intellect, physical attributes, psychosocial attributes, balance, and strength are recorded for each individual participating in bike camp.
3. Bike camp runs for 1 week, with 5 successive training sessions of 75 minutes each. Five sessions are held each day for 7 to 8 riders each.
4. Each participant is paired with one trainer, and they remain paired for the duration of camp.
5. The facility used needs to have a spacious flat floor area with no or few obstacles.
6. Two to 3 months following intervention, measurements of physical activity using Actical physical activity monitors are repeated.
7. Approximately 1 year following intervention, measurements encompassing areas of physical activity, physical attributes, psychosocial attributes, balance, and strength are repeated.
8. Trainers are required to interact with the rider's guardian to help identify methods used at home to motivate the rider and to manage the rider's behavior.

Specialized Equipment

Adapted Bicycle

The method to providing stability while learning involves mechanically modifying the bike so as to mitigate its instability.[b] The purpose is to begin with a stable, specially designed adapted bicycle and to incrementally progress to a 2-wheel bicycle. The progression can be altered to meet the individual needs of the rider[b]:

1. A rear handle is fitted to the bike so that the trainers can better protect and guide the participant.
2. The seats are typically larger in size and positioned lower so that the participant's feet are flat on the ground while seated on the bike.
3. The special rollers are fitted on the rear of the bike in place of a standard wheel. The rollers facilitate a movement that is similar to a 2-wheel bike, a simulation that training wheels cannot offer, minimizing the likelihood of falling.
4. The rollers prevent quick tipping by changing the effect of gravity on the bicycle. The roller has a wide, crowned surface, unlike the narrow surface of a standard bicycle wheel. When the bike tips on this wide, crowned surface, the mass of the rider is lifted so that the bike tips more slowly.[c]

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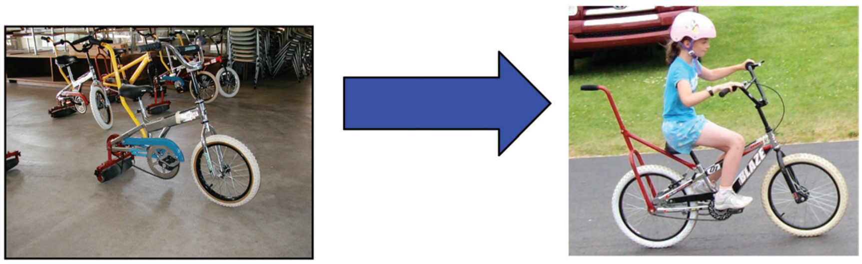
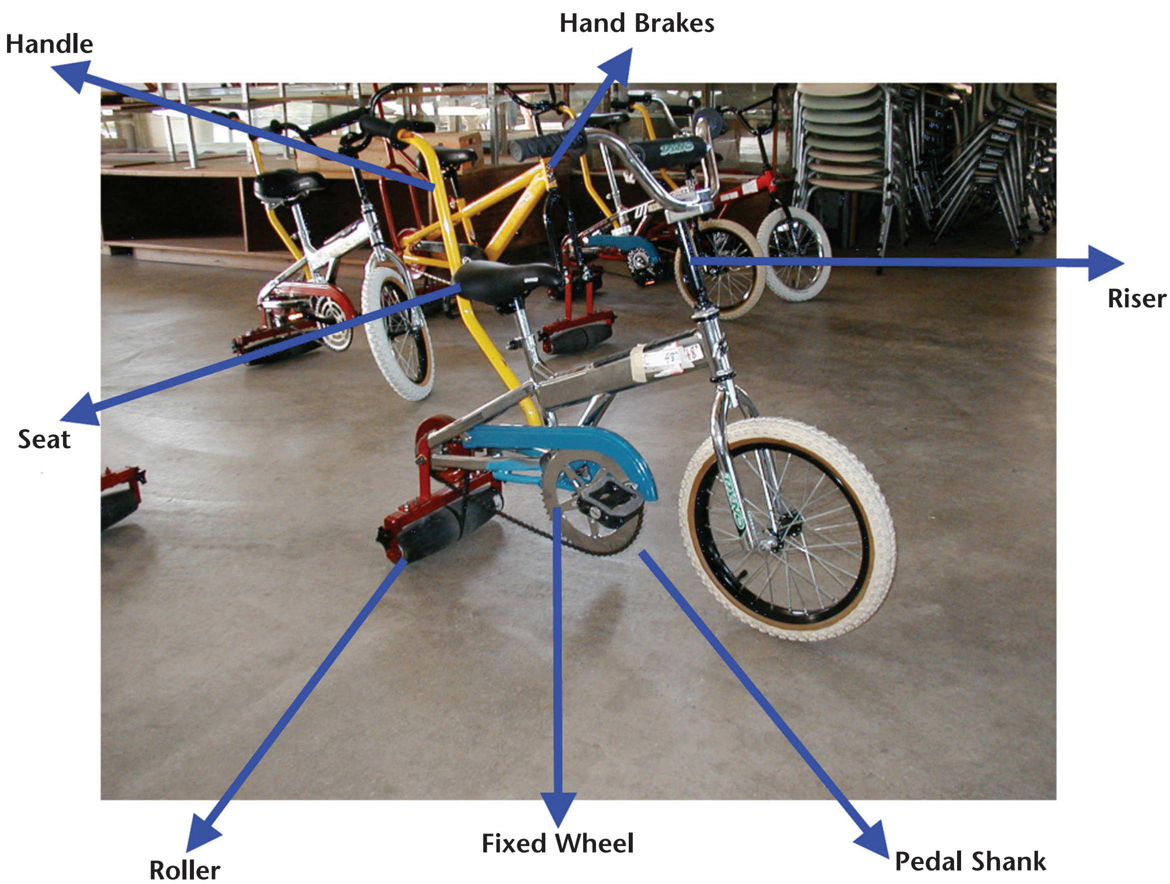
5. Roller wheels taper as they move up in difficulty from level 1 to level 8. These rollers aid in the progression of skills leading to riding a standard 2-wheel bicycle.

6. The drive train is fitted with a fixed wheel, meaning there are no pedal brakes and the pedals continuously rotate forward with or without force being applied.

Adapted Bicycle With Rollers → Standard 2-Wheel Bicycle With Spotting Handle



Bicycle With Adaptations



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7. The pedal shank is shorter, which, in turn, reduces the range of motion in the hip needed to complete a pedal rotation, minimizing loss of balance.
8. A riser is added to the handlebars to promote an upright, seated position while riding.
9. Hand brakes are used as the primary method of braking. Not having a foot brake minimizes the functions required for the rider's foot, allowing the rider to concentrate on pedaling forward. The hand brake is attached to the rear wheel of the bicycle only.

Training Team Roles

Floor Manager

During each camp, an experienced trainer assumes the role of floor manager. The floor manager has the responsibility of managing the training team and the teaching progression of each participant. The floor manager also is active in assisting the training team with communication with guardians. Specifically, the floor manager is responsible for the following:

1. Keeps logs of participant's skill level, equipment use, and progression.
2. Assesses and records participant's ability level.
3. Determines when participant is ready to progress to higher levels.
4. Provides trainers with teaching tips.

Bike Technician

During each camp, an experienced trainer assumes the role of bike technician. The bike technician has the responsibility of maintaining the adapted bikes and making adjustments to equipment such as adjusting handlebars, fitting the seat, and changing rollers. The bike technician also rides with the participant on a tandem bicycle, which allows the participant to experience how to correctly turn, brake, and pedal fast. Specifically, the bike technician is responsible for the following:

1. Adjusts bikes to meet each individual's physical needs.
2. Maintains bikes.
3. Adjusts bikes to higher levels.
4. Rides with participant on tandem bike.

Trainer

During each camp, a trainer is paired with an individual rider and is responsible for training that same individual for the entire duration of camp. Trainers have experience working with individuals with disabilities, and many have teaching or physical therapy experience. Trainers need to communicate with the participant and guardian to understand the unique learning style of that participant. With this information, the trainer is able to individualize the training strategy to meet the needs of the participant he or she is working with:

1. Trainers are paired with the same participant throughout camp.
2. Trainers have experience working with individuals with disabilities or teaching experience.
3. Trainers individualize their training strategy to meet the unique needs of each participant.
4. Trainers communicate with guardians to educate them on the training process so they can supplement continued training at home, monitor their child's riding, and encourage continued practice of the skills learned at camp.

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Individualized Training Strategies

Each trainer is responsible for developing a training strategy to meet the unique learning needs of each individual. Specifically, the trainer typically individualizes training using many of the following techniques:

1. Maintain minimal talking.
2. Reduce fear.
3. Eliminate falling.
4. Increase focus.
5. Guide steering.
6. Lean bike into turns.
7. Increase riding time, motivate individual to continue to pedal.
8. Reinforce positive behaviors.
9. Communicate with participant, guardians, and other team members.
10. Supplement communication as needed through ASL or picture vocabulary.

Training Progression

The adapted bicycles are designed to do the teaching. The training team facilitates the process. The participants learn to control and maintain the bicycle through their physical and visual experiences while riding, rather than through reliance on explanations and demonstrations.[b] Individuals, especially those with disabilities, learn more effectively with an experiential approach.[d] The training progression is designed to advance participants through a series of adapted equipment that can be individualized, providing experience and continued success at a pace that is appropriate for each rider. The training progression is outlined in the following:

Sequence of Training Progression

1. **Roller Bike**
   — Levels 1–8
   — Tandem bike ride with bike technician
   — Typically implemented for first 3–4 sessions
2. **Straight Launch**
   — Ride 2-wheel bike straight and practice braking with trainer spotting
   — Typically implemented in fourth or fifth session
3. **Brake Box**
   — Stationary braking practice while bike is immobilized
   — Typically implemented when rider struggles with braking during the straight launch trial
4. **Launch**
   — Ride 2-wheel bike for a longer distance on a straight or curved path and practice braking with trainer spotting
   — Typically implemented after successful straight launch with braking
5. **Self-Launch**
   — Practice self-starting the bike without trainer assistance
   — Practice self-launch, maneuvering and braking without trainer assistance
   — Typically implemented after much demonstrated success with launch, braking, and maneuvering

[a] The training manual should not be used or reproduced without permission from Lose the Training Wheels organization (http://losethetrainingwheels.org/contact.html).
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