The Physical Educator Vol. 72 • pp. 1–19 • 2015

METHODOLOGY

Heart Rate Profiles of Children With and Without Autism Spectrum Disorder in Response to Physical Play: A Preliminary Investigation

Casey M. Breslin, Mary E. Rudisill, Danielle D. Wadsworth

Abstract

In this study, the heart rate response of children with and without autism spectrum disorder (ASD) exposed to outdoor free play sessions during preschool was examined. Participants (n = 7; four children with ASD and three children who show typical development) wore Actiheart heart rate monitors during 6 school days. Using a single-subject design, the researchers found that children with and without ASD demonstrated a similar heart rate response to an outdoor free play period and similar participation as measured using PAHR-25 and PAHR-50 indexes. These children did not engage in adequate amounts of moderate to vigorous physical activity during free play. Thus, interventions should be developed to determine best practices for children with and without ASD to participate in adequate amounts of moderate to vigorous physical activity during free play.

Casey M. Breslin is assistant professor, Department of Kinesiology, Temple University. Mary E. Rudisill is Wayne T. Smith distinguished professor, School of Kinesiology, Auburn University. Danielle D. Wadsworth is associate professor, School of Kinesiology, Auburn University, Auburn University.

Thanks to Nathan M. Grier and Hannah M. Simoneau for assisting with preparing the data set for this manuscript. Thank you also to the teachers, parents, and administrators of the Auburn University Autism Center for allowing this research project to be conducted.

Please send author correspondence to Casey M. Breslin, Department of Kinesiology, Temple University, 249 Pearson Hall, 1800 North Broad Street, Philadelphia, PA 19122. E-mail: casey.breslin@temple.edu

Due the behavioral characteristics of autism spectrum disorder (ASD), children with ASD may be particularly at risk for being inappropriately engaged during unplanned free play, a common form of motor and physical activity (PA) programming for preschool-aged children. Free play is a high autonomy, child-driven opportunity for physical play in which no formal instructions, goals, or objectives are in place for the children to meet (Goodway & Branta, 2003; Robinson & Goodway, 2009). Researchers have suggested that preschoolers do not meet recommended PA guidelines during these types of play (Brown, Googe, McIver, & Rathel, 2009; McWilliams et al., 2009), yet this type of programming is pervasive in preschools.

Children with ASD, when left alone, without direct instruction regarding how to engage in appropriate physical play, are likely to behave inappropriately by withdrawing from their environment or exhibiting developmentally immature behaviors (Sherrill, 1998). Therefore, for children with ASD, unplanned free play may be spent engaging in sedentary, or otherwise inappropriate, behaviors (Pan, 2008a; Rosser Sandt & Frey, 2005). There are concerns that young children with ASD do not appropriately engage in PA during free play due to deficits in their communication and social interaction ability (Kangas, Maatta, & Uusiautti, 2012). Since children with ASD are at risk in free play settings, it is important to gain a better understanding of PA participation of children with ASD so appropriate educational experiences can be developed and implemented.

The results in recent research about the levels of PA participation by children with ASD have been inconsistent. Some researchers have found that children with ASD, when provided opportunities for PA, participate in less and lower intensity PA than their peers who show typical development (Pan, 2008a, 2008b). Other researchers have found that children with ASD participate in similar levels of PA as their peers who show typical development during recess, physical education (PE), and after-school activities (Bandini et al., 2013; Rosser Sandt & Frey, 2005). Specifically, Pan (2008a) examined the PA levels of Taiwanese children between ages 7 and 12 years in an inclusive recess setting, during which the children wore accelerometers. The researcher found that the children without ASD participated in an average of 7 more minutes of moderate to vigorous PA (MVPA) than their peers with ASD. The difference in recess time spent in MVPA between children with ASD (27.70% of recess time) and children without ASD (36.15% of recess time) was nearly 9%.

The PA levels Taiwanese children with and without ASD attained in PE settings were compared to those attained in recess settings (Pan, 2008b). These results indicate that MVPA participation levels are similar in PE settings. However, in recess settings, children with ASD engage in less MVPA than their peers who show typical development (Pan, 2008b). Rosser Sandt and Frey (2005), who also used accelerometers in their study, found the PA levels of American children with ASD between ages 5 and 12 years during PE, recess, and after-school hours were similar to those of their peers who show typical development. Children with ASD were found to participate in slightly less, albeit not significantly different, levels of MVPA at all time (i.e., all day totals, PE, recess, and after school) during data collection than their peers without ASD. Finally, Bandini et al. (2013), using accelerometry and parent report data to examine the PA habits of children with and without ASD, found that children without ASD participated in higher quantities of moderate PA during the week. In addition, they found no significant difference in PA levels between children with and without ASD for the week. The participants with ASD in all of these studies were of school age, and researchers have not compared PA levels of children with ASD enrolled in preschool to levels of their peers who show typical development. Additionally, heart rate monitoring has not been used in any studies to report PA levels of children with ASD; however, this technology has been used to measure the impact of self-injurious behaviors, stereotypes, and restraint devices on heart rate with children with ASD (Jennett, Hagopiana, & Beaulieu, 2011; Lydon, Healy, & Dwyer, 2013) and to measure cardiovascular arousal during brain imaging studies (Ming, Julu, Brimacombe, Connor, & Daniels, 2005).

In these previous studies, the PA engagement of children with ASD was explored using group statistical designs. This design, although popular in PE and kinesiology research, is useful for examining group effects, but not individual differences (Forbes et al., 2011). However, single-subject designs are used in the special education literature because the individual is a unit of analysis and researchers may include a smaller numbers of participants (Cakiroglu, 2012). In spite of the widespread use of single-subject designs in special education research, no researchers have used a single-subject design to report the heart rate response (and PA levels) of children with and without ASD.

Therefore, the purpose of this preliminary investigation was to determine the heart rate response and PA levels of children with

and without ASD enrolled in preschool in response to a free play PE experience using a single-subject design. Heart rate monitors are objective and reliable tools for measuring PA in young children (Benham-Deal, 2005; Brage, Brage, Franks, Ekelund, & Wareham, 2005; Durant et al., 1993; Parish, Rudisill, & St. Onge, 2007; Wall, Rudisill, & Gladden, 2009), but they have not been used to measure PA levels of children with ASD. Reports in the literature indicate that children with ASD engage in less PA than their peers who show typical development as measured using accelerometers (Pan, 2008a, 2008b) and that children with ASD experience an increase in heart rate response during periods of rest compared to their peers who show typical development (Goodwin et al., 2006; Ming et al., 2005). Due to the preliminary nature of this study, the dearth of information regarding heart rate response to exercise by children with ASD, and due to the conflicting reports in the literature regarding the differences in PA levels between children with and without ASD, no hypotheses were proposed. Instead, the purpose of this study was to provide descriptive information regarding heart rate response and PA levels in preschoolers as measured using heart rate monitors.

Method

Setting

Data collection occurred on the playground of a preschool that serves children who show typical development and children with ASD. The school specializes in instructing children with ASD, and the teachers use empirically based teaching strategies endorsed by the National Research Council through which they encourage all children to engage in learning activities. During the time of data collection, 17 children (seven children with ASD and 10 children who show typical development) were enrolled in the two classrooms at the school. Each classroom had one head teacher, two full-time instructional assistants, and two graduate student special education interns in the classroom at all times, to maintain a 1:2 teacher–student ratio. The children experienced an outdoor play session twice a day on a playground where they had access to climbing bars, four swings, three sliding boards, and two climbing ladders. They were allowed to access PE equipment (i.e., balls, striking implements, scarves, ribbons, hoppy balls, stilt cups, and balance disks) during outdoor playtime, and the teachers modeled physically active behavior and demonstrated appropriate equipment use. The teachers were also responsible for monitoring the children's behaviors

to ensure that the children were engaging in safe activities. When the children engaged in appropriate physical play, the teachers used praise as reinforcement. No formal lesson plans were created for the physical play period.

Participants

The participants in this study were enrolled at a small school located in a small city in the southeastern United States. No girls with ASD were enrolled in the school at the time of data collection; however, autism is 4 times more common among males than females (Solomon, Miller, Taylor, Hinshaw, & Carter, 2012). Institutional review board approval was obtained from the university sponsoring the research project. Parents provided informed consent prior to the start of the study, and participant assent was obtained prior to affixing the heart rate monitors. Participants ranged in age from 4.33 to 6.83 years (M = 5.31, SD = .87) and were recruited from one class to limit the influence of the teacher on PA participation. Preschoolers were included in the study if they assented to wear the heart rate monitor for the duration of data collection. Of the nine children (five with ASD and four without ASD) enrolled in this classroom, one child with ASD (a boy) refused to wear the Actiheart heart rate monitor on all 6 days of data collection and consent was not provided for one child to participate in the research. Seven children (four typically developing children [two girls and two boys] and three boys with ASD) were participants for the study. Children who showed typical development were included as a quasi-control group to show the heart rate response of children without ASD before, during, and after exposure to the same physical play session. A single-subject design was employed rather than a group design because subtler changes may be detected (Callahan & Barisa, 2005; Forbes et al., 2011).

Measures

Actiheart heart rate monitors. The Actiheart heart rate monitor (9.5 grams, 32.4 mm in diameter x 18.7 cm in length; MiniMitter, Bend, OR, USA) was affixed to the child's left side of the chest with electrocardiograph electrodes positioned on the skin between the fourth and the fifth intercostal spaces in accordance with instructions from the *Actiheart Physical Activity, Heart Rate, and Energy Expenditure Analysis Instruction Manual* (MiniMitter Company, 2004). The Actiheart was configured to sample heart rate at an ep-

och length of 15 s by calculating the heart rate through measurement of the elapsed time between two consecutive R-waves. Data were recorded and stored in the heart rate monitor until they were downloaded onto a computer using a standard USB connection. Actiheart monitors have been demonstrated to be reliable (αICC = 0.993) and valid in use with human populations (Brage et al., 2005) and specifically in child and toddler populations (Durant et al., 1993; Parish et al., 2007; Rowlands & Eston, 2007; Wall et al., 2009).

Physical activity heart rate indices. The intensity of engagement in physical play was calculated using the PA heart rate (PAHR-25 and PAHR-50) index (Durant et al., 1993), a measure of the percentage of time spent above 25% or 50% of the resting heart rate in a given time interval. The PAHR-25 index is an indication of light to moderate physical play and PAHR-50 is an indication of MVPA (Durant et al., 1993). These PAHR measures have been found to be reliable for use with young children during physical play sessions, with reported Cronbach's alphas for within day $r = .92$ and .88 and between day $r = .81$ and .56 (Durant et al., 1993). Because the children wore the monitors for the majority of their school day (including naptime), the mean of the lowest 10 consecutive data points (i.e., 2.5 min) of heart rate for each day of data collection was used to determine resting heart rate for that day. Children without ASD experienced their lowest 10 consecutive data points during the 90 min dedicated to naptime, indicating a true resting heart rate. However, because children with ASD experience poorer quality sleep than their peers who show typical development (Wiggs & Stores, 2004), the lowest 10 data points indicating resting heart rate for children with ASD did not necessarily occur during naptime. The mean resting heart rate (derived from all 6 days of data collection) was calculated for each child and used to determine each individual's PAHR-25 and PAHR-50 scores for each day.

Design and Implementation

Data were collected on Tuesday and Thursday every other week for 6 weeks for a total of 6 data collection days. Although the children experienced two 30-min outdoor free play periods per day (a morning and afternoon session), data were collected and analyzed from the morning free play period only. The morning play period was used for PE time and was supervised by the classroom teachers and student assistants. As the afternoon play period was used as recess only, it was sometimes used as a reward for positive behavior.

Because of the potential impact this "reward" would have on the PA participation levels of that play period, the afternoon outdoor play session was excluded from data analysis.

Procedures

On data collection days, an Actiheart heart rate monitor was affixed to participants upon their arrival at school, approximately 2 hr prior to the children's outdoor play period. Heart rate monitors were removed if a child expressed discomfort or dissatisfaction with the monitor or just before dismissal from school (after approximately 5 hr of wear), whichever came first. Since the children wore the heart rate monitors for a longer duration than that of the morning outdoor play period, the researchers were able to obtain a resting heart rate and a profile of each child's heart rate response to physical play. Data were collected on 6 days to determine a more reliable heart rate response of the child.

Data Analysis

Although participants wore the heart rate monitors for approximately 5 hr, the focus of this study was to monitor the heart rate data collected by the Actihearts for 30 min prior to the physical play period, during the 30-min play period, and for 30 min after the physical play period. The heart rate monitors had a 15-s epoch length, yielding 120 data points per participant during each 30-min period. The children wore the monitors prior to, during, and following the physical play periods, yielding 360 data points per participant each day of data collection. These 360 data points were then collapsed into a mean heart rate for each minute during the 90 min of interest before, during, and after the physical play period. Because of the descriptive nature of this study, mean heart rate per minute was calculated from the 15-s epochs. To do so, the four data points comprising each minute of data collection were collapsed to form a mean heart rate per minute.

The mean heart rate per minute from all 6 days of data collection was averaged to calculate the mean heart rate for the 30 min prior to, during, and following the physical play period. This data reduction process allowed the researchers to present a daily snapshot of the heart rate response and PA levels of children with and without ASD. Descriptive statistics (mean and standard deviation) were used to describe each child's heart rate response. Because the reduction process involved calculating the mean heart rate per minute across 6

days of data collection and the small sample size ($n = 7$), parametric statistical tests were not conducted. Rather, a single-subject design was used to highlight individual heart rate response attained during an unplanned free play period, and nonparametric statistical tests (Mann-Whitney test) were used to analyze PA levels as measured using PAHR-25 and PAHR-50 scores of children with and without ASD.

Results

Heart Rate Responses

The mean resting heart rate, mean heart rate before physical play, mean heart rate during physical play, and mean heart rate after physical play for each child are shown in Table 1. The data in Table 1 indicate that children with and without ASD have similar heart rate responses before, during, and after a physical play session.

Table 1
Participant Demographic Information and Mean Heart Rate Results for Resting, Before, During, and After Physical Play

		Heart Rate			
Participant	**Age**	**Resting**	**Before play**	**During play**	**After play**
1[a]	6 years, 10 months	89.8 ± 6.96	134.77 ± 6.81	145.44 ± 5.16	120.03 ± 4.60
2[a]	5 years, 6 months	91.7 ± 2.69	113.48 ± 3.28	129.79 ± 4.36	114.42 ± 2.17
3[a]	6 years, 0 months	88.9 ± 9.37	137.24 ± 3.68	145.35 ± 4.96	124.86 ± 6.18
4	5 years, 0 months	79.4 ± 5.59	115.85 ± 5.00	136.75 ± 4.31	117.52 ± 3.71
5	4 years, 9 months	86.1 ± 2.80	125.70 ± 10.93	144.49 ± 9.09	113.86 ± 5.92
6	4 years, 4 months	98.4 ± 2.07	149.81 ± 6.00	155.96 ± 6.23	113.86 ± 3.40
7	4 years, 4 months	87.9 ± 7.98	129.90 ± 4.89	150.58 ± 7.75	128.67 ± 3.79

[a]Children with ASD.

Physical Activity Levels

Mean PAHR-25 and PAHR-50 scores for children with and without ASD across the six outdoor free physical play sessions are shown in Table 2. As is evident by the percentages of time that the heart rates were above the PAHR-25 threshold points, both children with and without ASD spent a majority of their time in light to moderate PA. Six of the seven children spent very little time in MVPA as is evident by the percentage of time spent above the threshold for PAHR-50 scores. Using the Mann-Whitney test, the researchers found no difference between children with and without ASD for

resting heart rate, $U = 3.00$, $p = .29$, $r = .40$, and the percentage of time spent above PAHR-25, $U = 6.00$, $p = 1.00$, $r = .00$. However, the Mann-Whitney test indicated the percentage of time spent above PAHR-50 was greater for children without ASD than for children with ASD, $U = 0.00$, $p = .034$, $r = .801$.

Table 2
Average Resting Heart Rate (RHR), PAHR-25, and PAHR-50 Scores for Children With and Without ASD During Physical Play

Participant	RHR	PAHR-25	PAHR-50
1[a]	89.8	92.49%	10.19%
2[a]	91.7	75.84%	2.72%
3[a]	88.9	75.75%	23.12%
4	79.4	92.11%	54.61%
5	86.1	75.17%	31.03%
6	98.4	90.00%	60.00%
7	87.9	83.01%	26.80%

[a]Children with ASD.

The average heart rate in beats per minute across all 6 days of data collection is shown in Table 1. The average heart rates of the children in the study were similar across all 6 days of data collection (Figure 1). Minutes children with and without ASD spent in MVPA by day as measured using PAHR-50 scores are shown in Table 2. Two of the children with ASD obtained the most MVPA during the second day of data collection than all of the other children on all other days. The percentage of time spent in MVPA as depicted by PAHR-50 scores is shown in Figure 3. Most of the children (with and without ASD) spent less than 30% of the outdoor play period in MVPA. Two of the children without ASD obtained similar amounts of MVPA across all days of data collection, whereas in Figure 3, it is clear that one child with ASD was very physically active on the first and second day of data collection. However, the children without ASD did not participate in MVPA for more than 20% of the time.

Discussion

Despite the small sample size ($n = 7$), the preliminary data indicate that children with ASD and their peers who show typical development may exhibit similar profiles of heart rate response before, during, and after an outdoor physical play session in which teach-

ers modeled appropriate play activities. PAHR-25 scores indicated similar light to moderate PA engagement for children with and without ASD. However, when examining the mean PAHR-50 scores, the researchers found that children with ASD appear to participate in less MVPA than their peers.

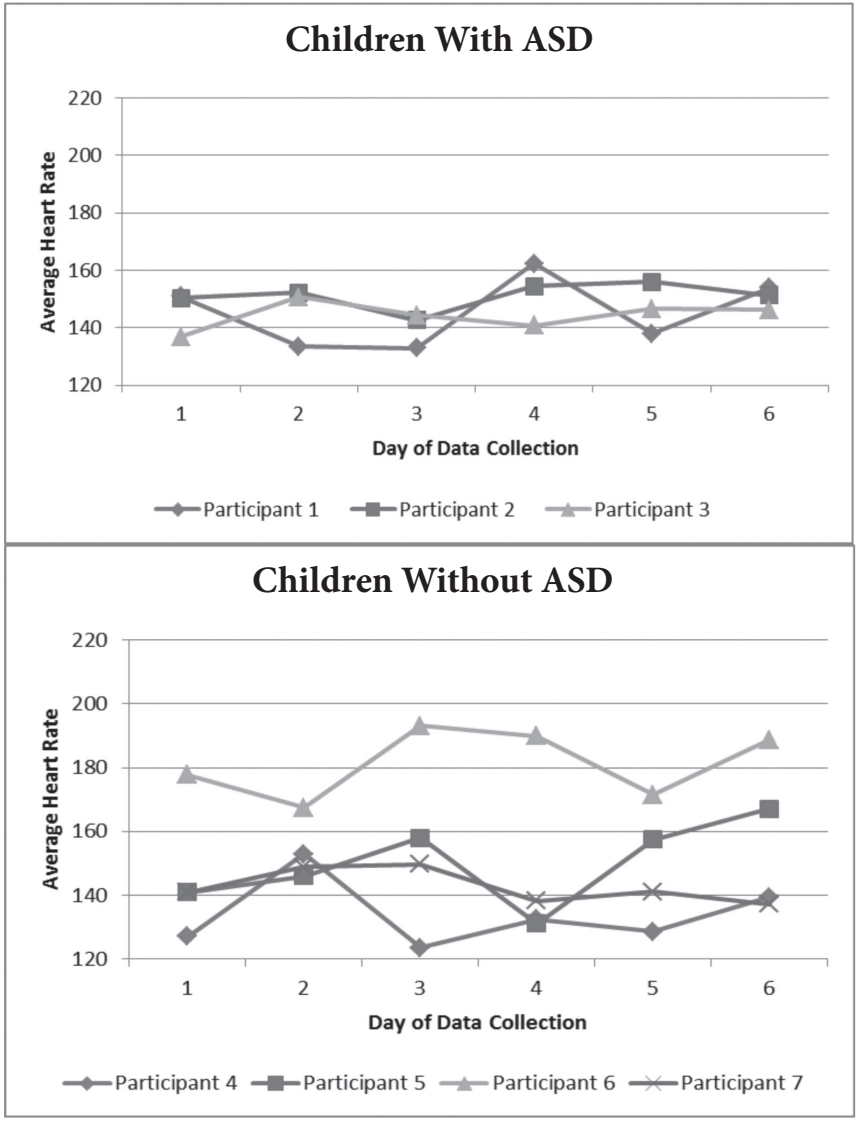

Figure 1. Average heart rate in beats per minute across all six days of data collection for children with and without ASD.

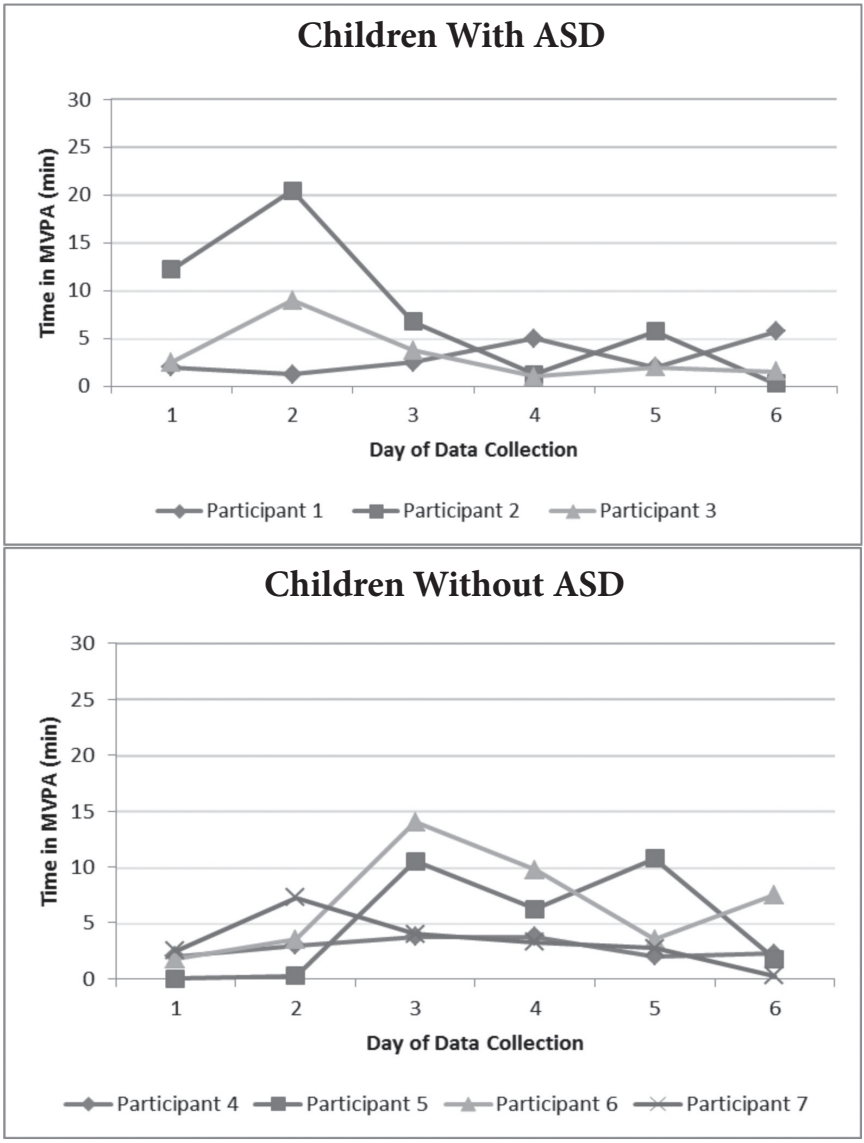

Figure 2. Time in minutes children with and without ASD spent in moderate to vigorous physical activity during free play across all 6 days of data collection.

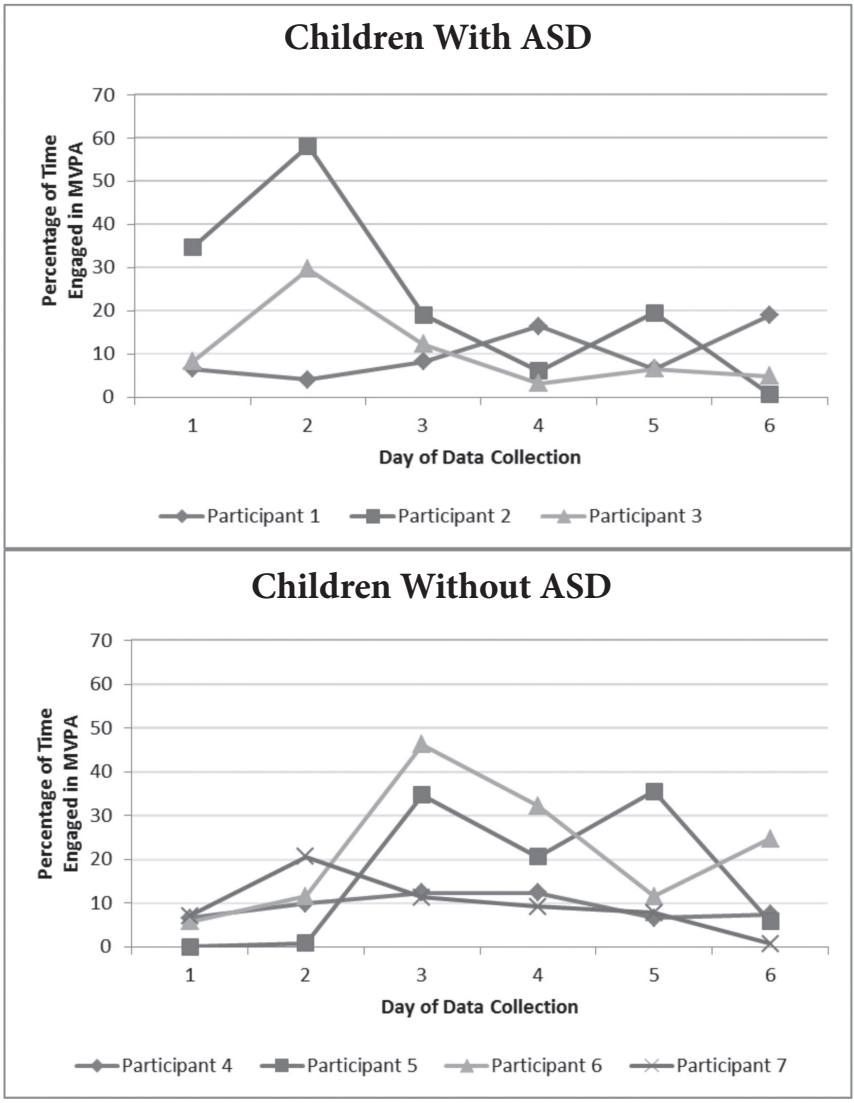

Figure 3. Percentage of time children with and without ASD spent in moderate to vigorous physical activity during the free play session across all 6 days of data collection.

The mean and standard deviations for heart rate before, during, and after physical play are shown in Table 1. All children exhibited a heart rate response within the range of normal for their age group (Malina, Bouchard, & Bar-Or, 2004; Wallis, Healy, Undy, & Maconochie, 2005). During the 30 min preceding the outdoor physical play period, mean heart rate response was between 113 and 150

bpm. During the outdoor play period, the mean heart rate range was between 130 and 156 bpm, and finally, during recovery from the outdoor play period, the children's mean heart rate was between 114 and 129 bpm. These findings indicate a similarity in the heart rate response to an outdoor play period, regardless of the presence or absence of an ASD diagnosis.

While examining the PAHR-25 and PAHR-50 scores to determine the children's PA levels, the researchers found that the four children without ASD spent a larger percentage of time participating in MVPA during the outdoor play period than the children with ASD. Similarly, all of the children with ASD and two children without ASD did not spend at least 40% of the free play session in MVPA. This 40% recommendation is the minimum percentage of time spent in MVPA during free play that, combined with other opportunities for PA throughout the day, would ultimately result in meeting the recommended daily PA guidelines (Ridgers, Stratton, & Fairclough, 2005). This recommendation was developed following an analysis of children's PA levels during outdoor free play (Ridgers et al., 2005). In that study, the children who participated in MVPA for a minimum of 40% of the outdoor free play session exceeded 30 min of daily PA. However, the outdoor free play sessions in that study were longer in duration, at an average of 85 min, than in the present study consisting of 30-min sessions. Nonetheless, all participants in the present study participated in light to moderate PA for the majority of the outdoor free play sessions (an average of 69.31% to 92.49%) as measured using PAHR-25 scores, and no statistical difference was found between children with and without ASD in light to moderate PA as measured using PAHR-25 scores. Thus, the data presented here is in support of the literature documenting that preschool children do not participate in adequate PA during outdoor free play periods during the school day (Brown et al., 2009).

Limitations

There are several limitations worth noting in this study. The first pertains to the sample of participants. The sample used in this study was small ($n = 7$) and contained no girls with ASD, which may limit the generalizability of the results of the study. However, given the increased prevalence of ASD in boys rather than girls, the information about heart rate response and PA levels of children enrolled in preschool from this study is valuable. The preschool used in this study may be an additional limitation to the study. This study examined children enrolled in a model educational program for children

with ASD. These children's teachers modeled appropriate PA during the outdoor play period, which may not be the case in other settings. Additionally, the results of this study cannot be used to imply that children with ASD or their classmates who show typical development do not attain adequate amounts of daily PA because PA during nonschool hours was not measured. Another limitation to this study is that information regarding the cognitive or communicative functioning of the children was not collected. Particularly for children with ASD, this factor may have had an effect on their play skills and behaviors during the outdoor free play period. It is not possible to say whether such factors had an effect on heart rates (and in turn, PA levels) because these data were not collected. Additionally, there was difficulty in obtaining a resting heart rate for the children with ASD, which could have had an impact on the PAHR-25 and PAHR-50 indexes. As the lowest 10 consecutive data points on each day of data collection were averaged to obtain the resting heart rate, and these were not necessarily obtained during naptime, it is possible that PAHR-25 and PAHR-50 indexes were skewed higher than appropriate. Thus, future researchers should consider employing a research design that allows for heart rate monitoring for 24 hr, to obtain a true resting heart rate response.

Difficulties researchers face when examining the heart rate response and PA levels of children with ASD in outdoor play settings were also examined in this study. Specifically, children with ASD may not be willing to wear devices designed to measure PA. On the last day of data collection, the teachers at the school where data collection occurred reported that some children (with and without ASD) disliked wearing the heart rate monitors. One child physically removed his heart rate monitor following the outdoor play period on 4 of the 6 days of the study. Additionally, information regarding the medications children consumed was not collected. Many medications (particularly the antipsychotic medications commonly prescribed to children with ASD) have an effect on heart rate, but it is not possible to say whether the medications children took had an effect on their heart rates because these data were not collected. Finally, heart rate and PA data collected in outdoor play settings could have been altered by the weather (Hajat, O'Connor, & Kosatsky, 2010). The fourth day of data collection, as per the researcher's field notes, was unseasonably warm, whereas other days included typical weather patterns for the climate in which the data were collected.

Suggestions for Future Research

Given the small sample size and the lack of parametric statistical testing employed in this study, further exploration of the heart rate response (and in turn, PA levels) of children with and without ASD during free play is needed. Additionally, researchers wishing to study PA levels of children with ASD using heart rate should obtain information pertaining to participants' medication use and participant enjoyment or tolerance of the heart rate monitor. Furthermore, information pertaining to the ambient temperature during data collection may also be valuable to interpretation of the heart rate data, as temperature may have an effect on heart rate (Ren et al., 2011).

Conclusions

Depite these limitations, the heart rate profiles and PA data from this study are a cause for concern regarding preschool policy. From a PA perspective, this study indicates that an outdoor free play setting does not provide adequate PA for children. The teacher-involved outdoor free play experience examined in this study would count toward the 60 min of structured PA recommended by the National Association for Sport and Physical Education (2002); however, the recommendations of Ridgers et al. (2005) may not be met. To obtain health benefits, Ridgers et al. recommended that children spend 40% of the recess physical playtime in MVPA. Only one girl without ASD met this recommendation on 1 day of data collection. Although this PE experience featured teacher modeling to show children how to use PE equipment to engage in PA, the data indicate that children who show typical development and children with ASD did not engage in adequate amounts of MVPA. These data are especially concerning as best practice for preschool PA programming is that teachers should model physical play for children during PA opportunities such as free play (McWilliams et al., 2009), yet the participants in this study still did not exhibit MVPA for a minimum of 40% of the free play period. Further research in this area is warranted, as this is a preliminary study only intended to report descriptive information. Thus, researchers should further explore the heart rate response and PA levels of children with and without ASD during unplanned free play and work to develop empirically supported strategies for increasing MVPA levels during free play and disseminate these findings to preschool policy makers.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., Rev. ed., pp. 69–84). Washington, DC: Author.

Bandini, L. G., Gleason, J., Curtin, C., Lividini, K., Anderson, S. E., Cermak, S. A., . . . Must, A. (2013). Comparison of physical activity between children with autism spectrum disorders and typically developing children. *Autism, 17*, 44–54. doi:10.1177/1362361312437416

Benham-Deal, T. (2005). Preschool children's accumulated and sustained physical activity. *Perceptual and Motor Skills, 100*, 443–450. doi:10.2466/pms.100.2.443-450

Block, M. E., & Davis, T. D. (1996). An activity-based approach to physical education for preschool children with disabilities. *Adapted Physical Activity Quarterly, 13*, 230–246.

Brage, S., Brage, N., Franks, P. W., Ekelund, U., & Wareham, N. J. (2005). Reliability and validity of the combined heart rate and movement sensor Actiheart. *European Journal of Clinical Nutrition, 59*, 561–570. doi:10.1038/sj.ejcn.1602118

Brown, W. H., Googe, H. S., McIver, K. L., & Rathel, J. M. (2009). Effects of teacher-encouraged physical activity on preschool playgrounds. *Journal of Early Intervention, 31*, 126–145. doi:10.1177/1053815109331858

Cakiroglu, O. (2012). Single subject research: Applications to special education. *British Journal of Special Education, 39*, 21–29. doi:10.1111/j.1467-8578.2012.00530.x

Callahan, C. D., & Barisa, M. T. (2005). Statistical process control and rehabilitation outcome: The single subject design reconsidered. *Rehabilitation Psychology, 50*, 24–33. doi:10.1037/0090-5550.50.1.24

Durant, R. H., Baranowski, H., Davis, H., Rhodes, T., Thompson, W. O., Greaves, K. A., & Puhl, J. (1993). Reliability and variability of indicators of heart-rate monitoring in children. *Medicine and Science in Sports and Exercise, 25*, 289–395. doi:10.1249/00005768-199303000-00015

Forbes, S. A., Ross, M. E., & Chesser, S. S. (2011). Single-subject designs and action research in the K–12 setting. *Educational Research and Evaluation, 17*, 161–173. doi:10.1080/13803611.2011.599555

Goodway, J. D., & Branta, C. F. (2003). Influence of a motor skill intervention on fundamental motor skill development of disadvantaged preschool children. *Research Quarterly for Exercise and Sport, 74*, 36–47. doi:10.1080/02701367.2003.10609062

Goodwin, M. S., Groden, J., Velicer, W. F., Lipsitt, L. P., Baron, M. G., Hofmann, S. G., & Groden, G. (2006). Cardiovascular arousal in individuals with autism. *Focus on Autism and Other Developmental Disabilities, 21*, 100–123. doi:10.1177/10883576060210020101

Hajat, S., O'Connor, M., & Kosatsky, T. (2010). Health effects of hot weather: From awareness of risk factors to effective health protection. *The Lancet, 375*, 856–863. doi:10.1016/S0140-6736(09)61711-6

Jennett, H., Hagopiana, L. P., & Beaulieu, L. (2011). Analysis of heart rate and self-injury with and without restraint in an individual with autism. *Research in Autism Spectrum Disorders, 5*, 1110–1118. doi:10.1016/j.rasd.2010.12.007

Kangas, S., Maatta, K., & Uusiautti, S. (2012). Alone and in a group: Ethnographic research on autistic children's play. *International Journal of Play, 1*, 37–50. doi:10.1080/21594937.2012.656920

Lydon, S., Healy, O., & Dwyer, M. (2013). An examination of heart rate during challenging behavior in autism spectrum disorder. *Journal of Developmental and Physical Disabilities, 25*, 149–170. doi:10.1007/s10882-012-9324-y

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity*. Champaign, IL: Human Kinetics.

McWilliams, C., Ball, S. C., Benjamin, S. E., Hales, D., Vaughn, A., & Ward, D. S. (2009). Best-practice guidelines for physical activity at child care. *Pediatrics, 124*, 1650–1659. doi:10.1542/peds.2009-0952

Ming, X., Julu, P. O. O., Brimacombe, M., Connor, S., & Daniels, M. L. (2005). Reduced cardiac parasympathetic activity in children with autism. *Brain and Development, 27*, 509–516. doi:10.1016/j.braindev.2005.01.003

MiniMitter Company. (2004). *Actiheart TM physical activity, heart rate, and energy expenditure analysis instruction manual* (Version 2.0). Bend, OR: Author.

National Association for Sport and Physical Education. (2002). *Active start: Physical activity guidelines for birth to five*. Reston, VA: American Alliance for Health, Physical Education, Recreation, and Dance.

Pan, C. Y. (2008a). Objectively measured physical activity between children with autism spectrum disorders and children without disabilities during inclusive recess setting in Taiwan. *Journal of Autism and Developmental Disorders, 38*, 1292–1301. doi:10.1007/s10803-007-0518-6

Pan, C. Y. (2008b). School time physical activity of students with and without autism spectrum disorders during PE and recess. *Adapted Physical Activity Quarterly, 25*, 308–321.

Parish, L. E., Rudisill, M. E., & St. Onge, P. M. (2007). Mastery motivational climate: Influence on physical play and heart rate in African American toddlers. *Research Quarterly for Exercise and Sport, 78*, 171–178.

Ren, C., O'Neill, M. S., Park, S. K., Sparrow, D., Vokonas, P., & Schwartz, J. (2011). Ambient temperature, air pollution, and heart rate variability in an aging population. *American Journal of Epidemiology, 173*, 1013–1021. doi:10.1093/aje/kwq477

Ridgers, N. D., Stratton, G., & Fairclough, S. J. (2005). Assessing physical activity during recess using accelerometry. *Preventative Medicine, 41*, 102–107. doi:10.1016/j.ypmed.2004.10.023

Robinson, L. E., & Goodway, J. D. (2009). Instructional climates in preschool children who are at-risk. Part I: Object control skill development. *Research Quarterly for Exercise and Sport, 80*, 533–542.

Rosser Sandt, D. D., & Frey, G. C. (2005). Comparison of physical activity levels between children with and without autism spectrum disorder. *Adapted Physical Activity Quarterly, 22*, 146–159.

Rowlands, A. V., & Eston, R. G. (2007). The measurement and interpretation of children's physical activity. *Journal of Sports Science and Medicine, 6*, 270–276.

Sherrill, C. (1998). *Adapted physical activity, recreation, and sport: Crossdisciplinary and lifespan* (5th ed.). Boston, MA: McGraw-Hill.

Solomon, M., Miller, M., Taylor, S. L., Hinshaw, S. P., & Carter, C. S. (2012). Autism symptoms and internalizing psychopathology in girls and boys with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 42*, 48–59. doi:10.1007/s10803-011-1215-z

Wall, S. J., Rudisill, M. E., & Gladden, L. B. (2009). Cortisol response to physical activity in African American toddlers attending full-time day care. *Research Quarterly for Exercise and Sport, 80*, 739–746.

Wallis, L. A., Healy, M., Undy, M. B., & Maconochie, I. (2005). Age related reference ranges for respiration rate and heart rate from 4 to 16 years. *Archives of Disease in Childhood, 90*, 1117–1121. doi:10.1136/adc.2004.068718

Wiggs, L., & Stores, G. (2004). Sleep patterns and sleep disorders in children with autistic spectrum disorder. *Developmental Medicine & Child Neurology, 46*, 372–380. doi:10.1017/S0012162204000611