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Physical Activity : Its Implication on Attention Span and Quality of Life in Children with Autism Spectrum Disorders

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Abstract— **This study examined the effects of physical activity on the attention span and health-related quality of life (HRQoL) of autism spectrum disorder (ASD) children in Singapore. Male participants (*N* = 12) aged 2-6 years, diagnosed with ASD were randomly assigned to either a physical activity or non-physical activity group. In the physical activity group, participants were administered 8 tri-cycling sessions; both groups of participants were measured for their attention span, and their parents completed the HRQoL questionnaires. Results indicate that as the exercise increases, the physical activity group demonstrated increasingly longer duration of attention span. These results extend the findings that physical activity enhances cognition of ASD children and support its consideration into the early intervention programs.**

Autism; early intervention; quality of life; physical activity; attention; children

I. INTRODUCTION

Autism Spectrum Disorders (ASD) are a range of neurodevelopmental disorders which includes Autistic disorder, Asperger's syndrome and Pervasive developmental disorder-not otherwise specified [1]. It impairs three broad areas which include social interaction, communication and stereotyped behaviours [2]. ASD is also most commonly co-morbid with anxiety disorder [3] which further complicates its management.

The prevalence for ASD in the United States of America (USA) was 6.7 in 1000 children [4] and the disorder is 4-5 times more prevalent in males than females [5]. In 2005, the estimated incidence of autism and Asperger's syndrome in Australia was 2.2 per 1000 children, aging from infants up to 5 years old and was about 6.3 in 1000 children between 6 to 12 years old; the male:female ratio of about 4:1 was also reported [6]. Consistent with the Australian data, an epidemiological study conducted in Singapore by Bernard-Opitz, Kwook, and Sapuan [7] reported similar gender distribution of ASD, and it was the foremost cause of disease burden among children below 14 years old [8]. In addition, the typical symptoms appear to remain constant throughout the lifetime [9] with poor prognosis [10]. Nevertheless, early intervention is strongly advocated for better management and productive development for ASD children [1].

II. AETIOLOGY OF AUTISM SPECTRUM DISORDERS

The exact aetiology is not known [11] due to the complexity of this range of neurodevelopmental conditions [12]. However, most of the possible explanations consisted mainly of factors from genetic and environmental influences [13]. Although ASD are associated with genetic factors, there is no particular gene that is fully accountable and multiple genes are believed to have contributed to ASD [14], in conjunction with other chromosomal disorders [11], environmental (e.g., toxins or stressful environment) and neurobiological factors [15].

A. Abnormalities in Brain Anatomy and Functions

There is evidence that the brain of the ASD children seems to enlarge significantly during the first year period of birth as measured by their head circumference [16], which was an outcome of increased cerebral volume: overall gray and white matter [17]; though Friedman et al. [18] discovered that the gray matter differences are more pronounced in ASD individuals than the white matter compared to typical developing children and those with delayed development. However, Eigsti and Schuh [19] found that the white matter in the brain of ASD individuals, which represents the connectivity, is not typical. Furthermore, it was also found that the communications/coordination among the brain hemispheres are restricted and compromised [19][15], possibly related to the structural abnormalities of the corpus callosum [20].

Most of the factors seem to show that there are impairments in the brain structures and/or functions and connectivity within and between the brain hemispheres, suggesting that ASD is a syndrome that involves the entire neural network rather than a specific area of brain abnormalities [17]. These imply a need for an intervention that is capable of targeting a wide range of impairments rather than a problem-specific solution.

III. MECHANISM OF PHYSICAL ACTIVITY

Physical activity has been viewed to have a vast positive effect on physical and mental health: affecting the central nervous system [21], circulatory system of the heart and the locomotor system [22], improve psychological aspects of well-being [24] and general well-being [25], enhance cognition [26] particularly on aspects of acquired skills or memory abilities [27] and maintenance of cognitive abilities relating to aging [28]. Of particular interest that has raised much evidence in the past few decades was the effect of physical activity on the central nervous system [27], specifically on cognitive processes.

The formation of healthy lifestyles is best during early childhood years where physical movements are critical milestones for the development of cognitive processes [29]. Given the importance of physical activity on typical developing children, more emphasis should be given to children with special needs [24], especially children with learning difficulties [30]. According to the DSM-IV-TR [5], ASD children have relatively short attention span, and are not able to focus on majority of the circumstances [31], which is an area of concern where early attentional impairments may affect the development of learning into adulthood as attention is an important factor for learning [2].

Previous research by Rosenthal-Malek and Mitchell [32] used exercise intervention on five male teenagers, average age of 14.9 years old, with autistic disorder and an average IQ of 42.2. Results indicated decreased in self-stimulatory behaviours, increased academic and work-related performance. Another study by Nicholson, Kehle, Bray and Heest [33] examined the effects of jogging on classroom involvements measured in seconds of four boys aged nine years, diagnosed with higher functioning range of the autism spectrum. The authors found that there was an increase in the classroom involvement time following participation of the exercise intervention (i.e., large effect sizes ranging from -0.7 to -1.5) and a positive correlation of the amount of physical activity with the level of academic involvement.

Unfortunately, the above studies did not provide sufficient information regarding their analyses and the lacked of control groups further prevented the generalisation of results. Nonetheless, they provided valuable insights on the potential of incorporating the therapeutic use of physical activity as part of early intervention in ASD children. However, an important question should be considered as to why physical activity may have a positive effect on children with ASD.

The mechanism of physical activity on learning and performance can be considered greatly under physiological aetiology [33]. However, Sibley and Etnier [30] have highlighted the possibility of reduced anxiety and elevated self-esteem hypothesis in enhancing cognitive functions after physical exercise. In contrast, Tomporowski, Lambourne and Okumura [34] summarises that this underlying mechanism may be partly attributed to the physiological factors in the brain but could also be contributed by other psychosocial factors and therefore a model that incorporates various fields of knowledge would be required to unveil this relationship.

A. Neurotrophins Regulations

Multiple studies have found that physical activity enhances cognitive performances, some in humans [35][26][27][36], and a possible explanation has centred on the neurotrophic mechanism, focused mainly on the brain-derived neurotrophic factor (BDNF) [25]. The idea underlying neurotrophic hypothesis is that the brain is modifiable [21] accordingly, to the demands by the introduction of the environmental [37] or behavioural stimuli through the development and enhancement of their connections [38], which have been associated with aspects of learning and recollection of memory [39]. The most evident stimulus that has the potential to trigger these changes is physical activity [26].

Coincidentally, the neurotrophic hypothesis seems to concur with the direction of the aetiology of ASD. These may suggest that if ASD are generally accepted as disorders related to the brains neural network [17] that are abnormal both in its neuronal connectivity and structures [20], it may thus be plausible that physical activity may act as a mediating factor that has the potential to influence the brain to modify its molecular structures and functions through the generation and enhancement of their connectivity, and therefore may induce the integration of the entire brain system to be in a state optimal for learning to take place [33].

B. Psychosocial Theory

The relationship between physical activity and psychological well-being has been widely studied [40]. According to the self-efficacy theory [41], self-efficacy perception functions as a critical factor for cognitive development. With higher levels of self-efficacy, thought processes are enhanced and allow the application of cognitive resources efficiently to the task at hand. Physical activity may represent an acquired successful skill that elevates the self-belief within the child in his/her ability and motivation to perform which act as a base reference that can be applied to other situational demands; this may be a plausible mechanism that explains the relationship between physical activity and cognition.

C. The Types, Durations and Intensities of Physical Activity

Though the effects of physical activity on cognition are well documented, the types, duration and intensities are not presently known [22] which are important considerations in the process of therapeutic implementation [23]. However, past research on children have utilised a range of 12 to 20 minutes of physical activity and had reported positive cognitive and behavioural gains [33][32], therefore, these studies provided a "safe time range" as a guide for the implementation of physical activity on children. Furthermore, Leppo et al. [29] recommended that exercise activity should be catered to the individual needs of the child based on their capabilities.

IV. Quality of Life

Another issue of importance yet with a dearth of literature is the Health-Related Quality of Life (HRQoL) of children with ASD [42]. Brewin, Renwick, and Schormans [43] mentioned that the goal for professionals is to enhance the quality of life of children especially those with developmental disabilities. This implies a need to develop interventions that specifically targets improving the quality of life of ASD children. A review of the literature has not identified any studies conducted to examine the effects of physical activity on HRQoL and attention span of ASD children in Singapore.

V. METHOD

A. Participants

Participants were 14 children aged 2-6 years that have been previously diagnosed with ASD according to the DSM-IV-TR [5]. In addition, all met the criterion of not having any physical disability, and were able to participate having had parental/guardian consent. Two of the participants were removed at the analysis stage due to an outlier and missing data. Overall, 12 male participants data were retained. Demographic summary are presented in Table 1. Participants were recruited from various early intervention centres in Singapore.

B. Materials

1) Sustained attention span task

The task included 24 cards with 12 identical pairs and was designed to be similar to the card-matching task conducted by Muller, Zelazo, Hood, Leone, and Rohrer [44]. Based on the baseline performance, the number of cards could be increased to 44 with 22 pairings if the maximum limit of the initial 12 pairs was obtained. This was to allow a proper measurement in detecting possible increase in the attention span. The task entailed finding pairs of identical cards facing down with two cards to be flipped each time for as long as possible. A simple demonstration with four cards of two pairings was shown each time to the participants before administering the attention task. The attention span was measured in seconds; began when the child was ready and ended when the child lost the attention on the task (e.g., looked away from the task, left the seat, messed up, threw the cards or did not continue on the task for a period of 10 seconds).

1) Pediatric quality of life inventory

The HRQoL was assessed using the Pediatric Quality of Life Inventory 4.0 (PedsQL) [45]. PedsQL is a questionnaire assessing the area of physical and psychosocial health (emotional, social and school/day-care functioning) in children aged 2-18 years. Each item is scored using a 5-point Likert scale ranging from (0 – Never, to 4 – Almost Always). The total scores are computed into a scale of 0-100, with higher scores representing higher quality of life. The scores were computed if at least 50% of the items are completed as recommended by Varni [45]. In addition, only completed items in the post-administration of the PedsQL that matched the completed items in the baseline administration were compared to allow for unbiased comparisons. Due to the difficulties in communication as commonly experienced by ASD children [42], only the parent proxy-report version for toddler and young children were adopted for this study. The toddler version has 21-items while the young children version has 23-items. The parent proxy-report has an alpha value of 0.90 and has shown to differentiate between healthy children and children with developmental conditions/disorders [46]. The PedsQL is also suitable for evaluation of intervention outcomes [47].

C. Procedure

Approval for the study was sought from the administrating institution's Human Research Ethics Committee. Once obtained, the initial 14 participants that agreed to participate were randomly assigned to either physical activity or non-physical activity group equally. Explanation of the study was given to the parents and verbal consent from the children was then sought. At the first session, baseline measurements were taken from both groups of child participants. In addition, the parents were asked to complete the PedsQL. At subsequent measurements, the attention task was repeatedly measured on three different trials separately for participants in each group condition. Lastly, the parents in both groups completed the same questionnaire on their respective last sessions. In total, all participants completed four trials of measurement on the attention task and their parents completed two copies of the PedsQL. All the tests administration are conducted at the respective residences of the participants and the exercise intervention were carried out at the nearby open areas or national parks. Table 2 shows the overall process of the research procedure.

1) Physical activity group (experimental group)

Child participants randomly assigned to the physical activity group participated in eight sessions of tri-cycling, each lasted for 15 minutes. The distance and speed covered were not measured due to the differences in the cycling ability among the participants. Time and place of the administration was also not controlled due to the variations of the participants' schedule and limitation of resources. However, all participants completed the required tri-cycling sessions at their own pace and capabilities, therefore the intensity was mainly of low to moderate levels. After the intervention was conducted on the fourth, sixth and eight sessions, participants were given the attention span task to measure the effect of post-intervention.

1) Non-physical activity group (control group)

Children randomly allocated to the non-physical activity group participated in four separate sessions on the attention span task. No additional activities were given as it was suggested that an actual control group not confounded by other given activities should be used to illustrate a clearer effects of physical activity [48].

VI. RESULTS

A. Assumption Testing

1) Attention span

Data were screened for mixed design ANOVA assumptions of normality, homogeneity of variance and sphericity [50]. In terms of normality, the duration on the attention task for physical activity group on trial 1, $W(6) = 0.79$, $p = .05$, and trial 2, $W(6) = 0.78$, $p = .04$; and for non-physical activity group on trial 0, $W(6) = 0.70$, $p = .01$, trial 1, $W(6) = 0.77$, $p = .03$, and trial 2, $W(6) = 0.73$, $p = .01$, were all significantly non-normal. In conjunction with normality plots and descriptive statistics, deviations from normality were detected with combined group skewness (i.e., lowest to highest on all trials) ranging from 1.03 (SE = 0.64) to 2.57 (SE = 0.64) and kurtosis ranging from -0.13 (SE = 1.23) to 7.38 (SE = 1.23) which confirms that the data were non-normal and highly positive skewed. In relation to the assumptions, the homogeneity of variance test shows that variances for the

TABLE I. SUMMARY OF PARTICIPANTS' DEMOGRAPHIC INFORMATION IN BOTH GROUP CONDITIONS AND OVERALL

		Number (%)	Mean Age	Standard Deviation	Sample Size
Physical activity			5.00	1.16	7
Race					
	Chinese	[a]6 (85.71)			
	Malay	1 (14.29)			
Gender					
	Male	[a]7 (100.00)			
	Female	0 (0.00)			
Non-physical			4.71	1.38	7
Race					
	Chinese	[b]5 (71.43)			
	Malay	2 (28.57)			
Gender					
	Male	6 (85.71)			
	Female	[b]1 (14.29)			
Overall			4.86	1.23	14
Race					
	Chinese	11 (78.57)			
	Malay	3 (21.43)			
Gender					
	Male	13 (92.86)			
	Female	1 (7.14)			

Note: In total there are only two participants removed at the early stage of analysis

[a] One participant removed due to outlier [b] One participant removed due to missing data

durations on the attention task were equal for both groups on trial 0, $F(1, 10) = 2.30$, $p = .16$, trial 1, $F(1, 10) = 3.14$, $p = .11$, and trial 2, $F(1, 10) = 3.40$, $p = .10$, however, the variances were significantly different between groups on trial 3, $F(1, 10) = 5.96$, $p = .04$. Together, the initial data analyses revealed violations of the assumptions of normality and homogeneity of variances across groups. In order to perform the required analysis, a natural logarithmic transformation of the data was performed prior to the analysis to correct for the violations [49].

The assumption of sphericity as indicated by Mauchly's test for the effects of trial was not significant, χ^2 (2) = 0.62, $p = .74$. Therefore the assumption was not violated and no correction required. In addition, it should be noted that Trial 0 was controlled as a covariate to account for the significant differences in baseline performances among both groups of participants, $F(1, 9) = 26.34$, $p = .001$, *partial* $\eta^2 = .75$.

1) Pediatric quality of life inventory

Data screening was also carried out on the PedsQL scores. Test of normality and homogeneity of variance for the PedsQL baseline and post scores of both groups of participants' revealed no violation of assumption for ANCOVA. The baseline PedsQL scores which is significantly related to the post-scores, $F(1, 9) = 41.16$, $p = <.001$, *partial* $\eta^2 = .82$, was assigned as a covariate to reduce baseline differences between both groups of participants.

B. The Interaction Effect of Trial and Group

There was a significant interaction effect between the number of trials and the group type when the effect of trial 0 was accounted, $F(2, 18) = 4.10$, $p = .03$, *partial* $\eta^2 = .31$. Planned contrasts revealed that the performance of trial 3 and trial 1 resulted in a significant interaction, $F(1, 9) = 8.17$, $p = .02$, $r = .69$. According to Fig. 1, participants in the physical activity and non-physical activity group performed similar at trial 1. However, as the number of trial increases, the individuals in the physical activity group had increasingly higher scores on the attention task with the highest performance on trial 3; while individuals in the non-physical activity group seem to have decreasing performance scores on trial 2; although there was a slight improvement on trial 3 but was still lower compared to their trial 1 performance. Overall, increased duration was more pronounced for the physical activity group than non-physical activity group. In general, this interaction suggests that the number of trials affected the increase in the duration on the attention span task of the participants in the physical activity group more than the participants in the non-physical activity group. ANOVA summary table are presented in Table 3.

TABLE II. SUMMARY TABLE FOR THE PROCESS AND ORDER OF RESEARCH PROCEDURES

Group	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8
Physical activity	AS PedsQL PA	PA	PA	PA AS	PA	PA AS	PA	PA AS PedsQL
Non-physical activity	AS PedsQL	AS	AS	AS PedsQL	-	-	-	-

Note: The activities/measurements are listed in order of administration.

AS – Attention span task, PedsQL – Pediatric Quality of Life Questionnaire, PA – Physical activity intervention

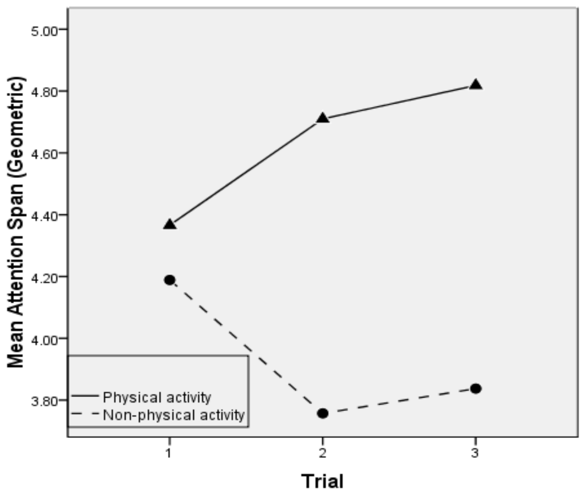

Figure 1. Mean performance on the attention span task across trials for both physical and non-physical activity group. Note that the values are in geometric units.

TABLE III. *SUMMARY TABLE FOR MIXED ANALYSIS OF VARIANCE OF THE EFFECTS OF TRIAL AND GROUP CONDITIONS ON THE OVERALL ATTENTION SPAN, WITH TRIAL 0 AS COVARIATE*

Source	***DF***	***SS***	***MS***	***F***	***P***	**Partial η²**
Covariate	1	5.32	5.32	26.34	.001*	.75
Trial	2	1.02	0.51	4.40	.03*	.33
Trial (Error)	18	2.09	0.12			
Group	1	1.13	1.13	5.62	.04*	.38
Trial x Group	2	0.95	0.48	4.10	.03*	.31
Error	9	1.82	0.20			

* $p < .05$.

C. *The Effect of Physical Activity on overall HRQoL*

There was no effect of physical activity after controlling for the effect of baseline PedsQL scores, $F(1, 9) = 0.73$, $p = .42$, $r = .27$. As the overall PedsQL were constructed based on physical and psychosocial indexes, further analyses (i.e., ANCOVA) were conducted to examine the effects of physical activity on the individual indexes.

1) e effect of physical activity on the physical functioning index

The covariate, pre-physical index scores, were significantly related to the scores on the post-physical index of the PedsQL, $F(1, 9) = 46.52$, $p < .001$, *partial* $\eta^2 = .84$. However, there was no significant group effect on the post-physical index, $F(1, 9) = 0.05$, $p = .82$, $r = .08$.

2) The effect of physical activity on the psychosocial functioning index

The pre-psychosocial index scores, controlled as the covariate significantly affected the post-psychosocial index scores on the PedsQL, $F(1, 9) = 27.07$, $p = .001$, *partial* $\eta^2 = .75$, but the effect of group was not significant, $F(1, 9) = 0.78$, $p = .40$, $r = .28$. However, as the psychosocial index is comprised of emotional, social and school subscales, further ANCOVAs were carried out individually for the subscales to examine any possible effect of physical activity on the subscale level.

The emotional and school post subscales scores after controlling for their individual pre-subscale scores were not significantly different among the groups. In contrast, with the pre-social subscale scores as a covariate, $F(1, 9) = 72.13$, $p < .001$, *partial* $\eta^2 = .89$, a significant group effect was detected on the post-social scores, $F(1, 9) = 8.36$, $p = .02$, $r = .69$. Descriptive statistics shows that the participants in the physical activity group have higher post-social scores ($M = 56.39$, $SD = 5.60$) than participants in the non-physical activity group ($M = 46.95$, $SD = 5.60$) after the effect of their pre-social scores are controlled for.

VII. DISCUSSION

The purpose of this study was to investigate the effects of physical activity on the attention span and quality of life of children with ASD.

A. *Physical Activity on Attention Span*

Participants exposed to physical activity shown longer duration of their attention span on the attention task as the number of exercise session increases. This indicates that with continuing exercise interventions, participants were able to demonstrate improvement on the duration of their attention span. In addition, the comparison to a control group not exposed to any activities given by the researcher further elucidated the effects of physical activity on children with ASD.

Past studies have indicated that activity that requires high focus would trigger the brain system in enhancing the ability to learn or perform [50][51][52][53]. Collectively, it may suggest that there could be other tasks that may have a similar effect but are perhaps difficult to get the child to engage on the task. Conversely, physical activity may have indirectly “forced” the child to maintain focus on the task which may have triggered the system and therefore are more likely to be effective in enhancing cognitive functions compared to non-physical activities. Furthermore, according to the neurotrophic hypothesis, the brain system is modifiable [21] through behavioural stimulus [38]. Taken together, may account for the improvement in attention span observed in the current study.

However, Sarter, Gehring and Kozak [52] argued that participant’s motivation is also an important factor in activating the enhanced brain system in response to underperformed situations. According to self-efficacy theory [41], a successful performance provides a sense of fulfilment and further seeks accomplishment of challenging task to gain task satisfaction, which fosters perseverance. This was indeed indicated by the longer duration on the attention task as the number of exercise session increases, which may reflect enhanced persistence (i.e., motivation) in task performance.

In general, given the current findings in the context of previous studies, it is plausible to suggest that physical activities are beneficial to the improvement of attention span in children with ASD.

B. Physical Activity on HRQoL

Consistent with the findings of Bakken et al. [54] where short-term physical activity (i.e., eight weeks) was not able to derive the improvement on physical health. Indeed, this was indicated by the non-significant differences observed on the physical index of the PedsQL. Alternatively, it may be probable that the number of exercise sessions in this study was too short to adequately show the effects of improving the physical aspect and hence the overall HRQoL.

Interestingly, although the overall HRQoL of ASD children did not improve following the exercise intervention, the social functioning subscale of the PedsQL was higher in physical activity group participants. Albeit speculative, this may possibly reflect the improvement of the social functioning aspect of the participants after exposing to exercise interventions. Though surprising, this result is consistent with a finding by Bass, Duchowny and Llabre [55] that ASD children aged 5 to 10 years demonstrated improvement in their social functioning after 12 weeks of horseback riding.

The current observation may also be related to the opportunity for social engagement that existed in these exercise settings [24]. However, participating in social opportunity settings does not naturally facilitate the improvement of social relationships [56]. In addition, such opportunity also existed in early intervention settings [57] which the current participants are attending.

As social functioning skills are needed to be developed through learning, intervention that facilitates this aspect would be necessary for individuals to gain benefit from social settings [57]. This suggested that some form of learning might have occurred during the process of the exercise intervention. It is widely recognised that ASD individuals have brain neural network abnormalities which may have resulted in the inability to synthesise information [17] between both hemispheres, where their coordination are imperative for learning to occur [33]. Furthermore, there is evidence to suggest that physical activity is capable of triggering the brain's ability to change [26] through the enhancement of their coordination which may prime the brain to be in a state optimal for learning [33]. Taken together, it is conceivable that participants exposed to physical activity may have experienced certain physiological changes in the brain that allowed for optimised learning to occur which may have accounted for the social improvement seen in this study. Alternatively, it may also be that the participants experienced the positive post-exercise effect of reduced stress and anxiety [30], and improvement of mood [58] and thus are more able and willing to engage in social interactions; resulting in the improvement of their social functioning.

Overall, impaired social functioning is a core aspect of ASD [2]; improvement in this area may indicate the possibility of physical activity as a potential therapeutic intervention that is beneficial to children with ASD. However, it is noteworthy that this interpretation would require further investigation as the current measurement is a subscale of the PedsQL consisted of limited items and thus may not reflect the overall level of social functioning.

C. Implications to Early Intervention Focus of ASD

From the results of this study, ASD participants were able to improve their attention span and aspects of social functioning indicated that they have the potential to improve their learning provided that the right stimulus is applied to elicit this effect [59]. Although not being able to be shown in this study, physical activity may have improved the neural connectivity of the bilateral hemispheres, making the brain more receptive to learning [33]. This suggested a "golden hour" period where the brain is optimised towards learning after physical activity. Based on this assumption, a brief form of physical activity prior to any form of learning may perhaps be an effective stimulus in enhancing the child's ability to benefit better from early intervention services where certain form of learning is required [57].

Given that cognitive improvement are seen after various types of physical activities [37][33][32], suggested that the causal factor for the effects seen cannot possibly be attributed to any specific activity. In view of the current study and the above cited research, it is perhaps reasonable to suggest that the common underlying trigger among the observed phenomena is physical activity. This interpretation is crucial to ASD population as any types of physical activity that requires attention will be beneficial to the child; provides the flexibility of utilising any form of physical activity that are suitable to the child's needs, capability and interest, and the availability of time/cost-effective resources and simple administration. Nevertheless, it is important to note that this study do not suggest that physical activity alone is sufficient as a therapeutic measure for ASD children but instead the incorporation of such activity may complement and/or enhance the effectiveness of other early interventions or learning strategies.

D. Limitations

Firstly, despite incorporating a larger sample size compared to previous studies [33][32], the current sample is still limited and thus must be considered as a pilot study. Secondly, the unequal treatment time between the experimental and control group may have introduced certain biasness to the nature of the results. Thirdly, the confirmation of the ASD diagnosis was not carried out. In relation, the type and severity of the ASD participants were not known. However, considering the results of this study together with previous studies [33][32] that uses high and low functioning ASD children, the positive effects associated with physical activity are likely to be applicable to the entire spectrum. Nevertheless, it is necessary to further evaluate this proposition.

Furthermore, the distance and intensity of the exercise intervention were not controlled. However, as participants were able to display increased in attention span and social functioning, perhaps it is not necessary to restrict or pressure the child in reaching a certain level of physical skills and that a pace that the child is comfortable with is sufficient in deriving the cognitive and social benefits associated with physical activity.

E. Future Studies/Directions

In view of the above limitations, case studies would be useful in determining the appropriate type of physical activity for ASD individuals (i.e., individual differences). Furthermore, future studies can consider utilising a specific tool towards measuring the social functioning of ASD children following post-exercise intervention. In addition, higher number of exercise sessions can be used to detect the maximum level of improvement (i.e., ceiling effect) and the durability of the positive effects. Lastly, it may be worth to evaluate whether physical activity prior to any forms of therapy, early intervention or learning sessions could increase the learning/therapeutic outcome of children with ASD and perhaps even to children with specific learning difficulties.

VIII. Conclusion

Extending previous research [33][32], the current study further demonstrated the positive effects of physical activity on cognition in children with ASD. The methodology used in this study provided a clearer illustration of the post-effect of physical activity in improving the attention span and aspects of social functioning of ASD children. Notwithstanding its limitations, the current study in conjunction with existing literature raised the possibility that the observed phenomena are unlikely to be activity-specific and instead may be a function of high focus activities where any form of physical activity that are likely to cause the child to engage on task are likely to be successful in triggering the brain system to be receptive towards learning. In addition, individual differences, motivation, self-efficacy, mood, level of stress and anxiety are possible contributory factors towards the relationship between physical activity and cognition. While the mechanism underlying this relationship remains controversial, the benefits of physical activity on cognition appear to be unequivocal; particularly to ASD children, its implication towards early intervention are likely to be beneficial and thus its inclusion should be encouraged. Further considerations in extending this research towards other clinical populations are an area that warrants attention.

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