**Abstract:**

Purpose: Examine the relationship between Energy Expenditure Index (EEI), Rate of Perceived Exertion (RPE), and fatigue in the classroom for children with disabilities and provide a research-based study design to initiate a standardized way of determining the most appropriate assistive device (AD) in the school setting. Methods: Databases searched include PubMed, CINAHL, Cochrane, ERIC, PEDro, REHAB DATA, and Education Full Text. Inclusion criteria include children aged 4-21diagnosed with disability, use of EEI or RPE, published in English, and research completed in the last 15 years. Exclusion criteria include studies published prior to 2001 and studies not published in English. Results: Overall, quality and level of evidence of studies were low. Only 9 studies were found that met inclusion and exclusion criteria. One study investigated the effect of utilizing different ADs in the school setting, but results were not statistically significant. Conclusion: Current research supports the use of EEI and modified RPE measures in the population. More research needs to be conducted on the feasibility, validity, and reliability of utilizing EEI and RPE to determine need for more supportive AD in the school setting. Evidence found via the literature review was low quality and inconclusive. A research-based study design is provided to encourage school-based physical therapists to add to this body of research.

**Introduction:** Current research indicates there are many positive effects of intermittent physical activity during the school day1,2,3,4. Physical activity interspersed throughout the school day as an “active break” opportunity has been correlated with decreased off-task behavior1, a decrease in student lack of effort in the classroom2, decreased inattentiveness in the classroom2, improvement in mathematical scores3, and an increase in physical activity outside of the school setting4. The majority of the current research is focused on typically developing children and may not carry over to those with developmental disability or debilitating injury.

 The general benefits of physical activity for children with disabilities are vast, including improved gross motor function5, increased child and parent satisfaction/quality of life5,6, prevention of secondary conditions6, lowered energy costs of movement7, and improved aerobic capacity5. Specific studies have not been completed on the benefits of intermittent exercise during the school day with this population. Certain childhood disabilities make children more susceptible to fatigue both in and out of the classroom. Children with cerebral palsy (CP), traumatic brain injury, or mitochondrial disorders not only battle chronic fatigue, but also fatigue faster during exercise than their typically developing and able-bodied peers8,9,10.

 For this reason, school-based physical therapists are put in a conundrum. Current research suggests that increased activity in a high-intensity interval training (HIIT) fashion would improve a typical student’s performance in school3,4. However, there is a major concern among school-based physical therapists (SBPTs) about whether use of a less restrictive assistive device (AD) would be beneficial or detrimental to a child with disability’s learning ability. Use of a more supportive AD decreases the amount of exertion required for ambulation. Utilization of a less supportive device will require an increased amount of energy and effort from the child which causes an increase in heart rate, much like exercise.

 According to the Individuals with Disabilities Education Act (IDEA) – Part B, physical therapists in the school system are required to address education-related needs11. Physical therapists must work alongside teachers, faculty, and the student’s parents to provide best access to the student’s educational environment. While in the outpatient setting physical therapists provide treatment deemed medically necessary, school based physical therapy is required to be educationally relevant. For this reason, many school-based therapists face the decision of whether to utilize a more or less supportive AD. A less supportive AD will allow the child more physical activity and exertion, and provide the student with an increased sense of autonomy. A more supportive AD may allow the child to achieve increased success in the classroom.

 A reliable measure for energy cost needs to be identified in order to understand the value of a more or less supportive AD in the school setting. This review of literature focused on 2 measures: the EEI and RPE. Each offer information valuable to PTs from different perspectives which can inform their decision-making and clinical reasoning.

The energy expenditure index (EEI), also termed the physiologic cost index, has been found valid and reliable for children with and without disabilities in determining effort/cost of ambulation12. Studies including children with CP, Duchenne muscular dystrophy, and myelomeningocele have all used the energy expenditure index (EEI) to determine physiologic cost of ambulation with and without ADs13,14,15. The EEI is a more cost-effective way of determining energy expenditure as compared to the Oxygen Consumption Index and generalized Oxygen Consumption due to the lack of specialized equipment necessary to perform the EEI. Energy expenditure is calculated by first taking a resting HR (following 5 minutes of relaxed sitting), timing a child ambulating a pre-determined distance with a stop watch, and taking an additional heart rate reading following ambulation. Therapists only need a stop watch, measuring tape, and heart rate monitor to complete the assessment. The formula is as follows12:

EEI = walking HR-resting HR
 walking speed

 = beats/min – beats/min
 meters/min

 = beats/meter

 A measure frequently used to gain insight to the child’s perspective of exertion is the RPE. Utilization of rate of perceived exertion (RPE) in children with and without disabilities has been under debate for many years. Groslambert and Mahon formulated a review on the influence of age and cognitive development on use of RPE16. Children ages infant to three years old were found to lack the cognitive ability to rate their exertion during an activity. As children reach the pre-operational period (ages 4-7 years), their ability to quantify RPE improves. Research indicated that the Children’s Effort Rating Table (CERT) may be most appropriate for this age range as opposed to the Borg RPE (6-20)16 due to the use of pictorials and reduced cognitive requirement of the assessment. There is good evidence to suggest that utilization of the OMNI RPE scale is most feasible, accurate, reliable, and valid for children aged 8-12 years old as well as those between the ages of 13-1816. Children with lower cognitive abilities are better able to understand pictures than a numerical scale, making the OMNI RPE and CERT better options for this age population than the classic Borg RPE.

 Though the EEI and RPE have been utilized to determine cost effectiveness of ambulation, no studies have investigated the combination of these two in predicting fatigue in the school setting following ambulation.

 The purpose of this review and prospective study design is to examine the relationship between the EEI, RPE, and fatigue in the classroom. A second aim of this research is to begin the process of generating a standardized, inexpensive, and accessible way of determining need for more supportive AD in the school setting.

**Methods:**
 Databases searched include PubMed, CINAHL, Cochrane, ERIC, PEDro, REHAB DATA, and Education Full Text. The PICO question chosen for this literature review is as follows: In school-aged children with disabilities, are the RPE and EEI effective at predicting fatigue in the classroom? The exact search strategy utilized can be found in Table 1 below. All abstracts and titles of search results were read to determine whether they met inclusion criteria. Studies were only included if they met inclusion criteria and were published after 2001.

Inclusion Criteria:

* Studies involving school-aged children (4-21 years old)
* Use of RPE or EEI
* Published in English
* Conducted in the last 15 years
* Diagnosis of a disability

Exclusion Criteria:

* Children without disability
* Individuals not between the ages of 4-21 years old

Inclusion and exclusion criteria were chosen in an attempt to detect all articles utilizing the EEI and RPE in children with disabilities. The fifteen year publication limit was utilized to ensure research included was accurate and up-to-date.

Due to the variety of RPE measurements used for children with disabilities in research, the general “rate of perceived exertion” phrase was included in the search strategy. Utilization of RPE in the search strategy was meant to catch all measures including the Borg RPE, OMNI RPE, and CERT RPE and allow the researcher to gather information regarding the most popular scale for children with disabilities.

Studies failing to meet inclusion criteria were discarded. All studies meeting these criteria were read and scored for quality via the Downs & Black checklist, PEDro Scale, or AMSTAR Scale as appropriate. Articles were then critiqued by the sole researcher and sorted based on relevance. If the research was unsure of whether an article met inclusion criteria, the article was read in full and analyzed. Following further analysis all articles were able to be categorized as meeting or not meet specified criteria. Alternate methods of ruling in or out were not necessary. All searching, scoring, critiquing, and analyzing was completed by the sole researcher.

Table 1: Terms used to guide search

|  |  |  |  |
| --- | --- | --- | --- |
| **P**atient/Client Group | **I**ntervention (Assessment)  | **C**omparison  | **O**utcomes  |
| * School-age\*
* Child\*
* Disable\*
* Disabilit\*
 | * Rate of perceived Exertion
* RPE
* Energy Expenditure Index
* EEI
 |  N/A  | * Fatigue\*
* Class\*
* Tire\*
* Cogniti\*
* Perform\*
 |

Proposed Search Strategy:
1. School-age\* OR child\* OR disability\*
2. Rate of perceived exertion OR Energy Expenditure Index OR EEI
3. Fatigue\* OR class\* OR tire\* OR cogniti\* OR perform\*
4. 1 AND 2 AND 3

**Results:**

Nine research articles were selected utilizing the search strategy. Table 2 outlines how many journal articles were retrieved from each database that met inclusion and inclusion criteria. Table 3 contains the quality score, level of evidence, and type of research for each article selected.

Overall, quality of studies and level of evidence were low. Only one article investigated the effects of utilizing different ADs in the school setting16. The extreme lack of research on this subject matter is evident by the use of 7 databases with only 9 articles meeting inclusion criteria. Of the nine articles, four were level 4, two were level 3B, one level 2C, one 2B, and one 1B.

Four articles investigated the effects of different ADs or orthotics on energy expenditure.17.18.19. Each article determined the EEI was an appropriate, reliable, feasible, and valid measurement to use in children aged 4-21 with disability. RPE measures were not utilized in the four articles concerning differences in ADs and orthotics. Three research articles utilized the EEI to determine the effectiveness of an exercise program for individuals with disabilities20,21,22. Two of the three articles found no significant change in EEI following specific exercise programs20,21. The third article found differing effects for each child of EEI following a fitness program22. Inadequate responsiveness of the EEI may be inferred from these articles. However the two articles are of low quality and it is equally as likely that the exercise programs implemented were not of high enough intensity or duration to change EEI for participants.

The final two research articles investigated the differences between the typically developing population and children who have acquired a traumatic brain injury (TBI)23 or were diagnosed with CP24. The study by Katz-Leurer and colleagues23 demonstrates that children with a history of TBI have a higher OMNI RPE while completing physical activities than do children who have not suffered a TBI. Katz-Leurer and colleagues23 also determined that children post-TBI have lower levels of recreational physical activity than their peers. EEI was not statistically significantly higher in children with TBI – which could be due to extent of motor involvement not documented in the research article. Mailtais and colleagues utilized the RPE as one of many measures to determine the response of children diagnosed with CP to treadmill walking in a heated environment. RPE was not statistically significantly different between individuals with and without CP, though differences were found in body temperature, heart rate, and steady-state VO2 max. This may indicate that the Borg RPE is not responsive to these changes. On the other hand, a lack of statistically significant change may also be attributed to the children’s inability to fully comprehend the Borg Scale (6-20), or the fact that children living with CP are accustomed to working harder in higher temperatures.

Lephart and colleagues16 utilized the EEI for one child with CP who ambulated with both a posterior walker and forearm crutches. Lephart found that the EEI for gait using a posterior walker was 47% higher than the EEI calculated during ambulation with forearm crutches. No statistically significant difference between the two ADs was found for fine motor accuracy or task completion time following ambulation. Though this study did not address a student’s ability to concentrate and stay on-task in the classroom, it provides structure for future research. Strengths of this study include the score of 16/20 on the Downs and Black Checklist, excellent explanation of procedure and outcomes, and relevance to the subject matter being reviewed. Weaknesses include a sample size of one (leading to low external validity), a lack of healthy control, and an inability to blind subjects and researchers as to which AD was being utilized. Overall quality of the article is fair (+), and it suggests that EEI is feasible and effective at determining differences in effort between ADs.

Results of the study by Konop and colleagues17 are in agreement with the article by Lephart that the EEI is accurate at determining differences in effort between ADs. The Konop article investigated the effects of different walkers on energy expenditure and upper extremity kinetics. Results show an increase in EEI when participants with CP utilized an anterior walker17 – demonstrating that use of an anterior walker is more work and burdensome to the child. Strengths of this article include relevance to the literature review topic and clear explanation of findings. Konop and colleagues scored a fairly low 11/29 on the Downs and Black checklist and was rated at evidence level 4. Overall quality of the study is poor, however, it supports the use of EEI in determining energy costs of different ADs.

Uckun and colleagues18 completed a similar study in which EEI results were compared for use of differing lower extremity orthoses. Statistically higher EEI values were recorded when children with CP wore plastic orthoses, including solid posterior ankle-foot orthoses (PAFOs)18. This study demonstrates the EEI’s ability to detect differences in energy output between differing lower extremity orthoses – which likely takes greater precision than determining differences in walkers or other ADs. This study was rated 2B and scored 11/29 on the Downs and Black checklist. Overall quality of the article is fair (+) and it provides important information on the sensitivity of the EEI.

The fourth and final relevant article found via the search strategy was unable to show a statistically significant difference in EEI based on type of orthotic worn by children with CP19. Though this could point towards a lack of responsiveness of the EEI, a lack of change could also be attributed to weaknesses of the study such as a low number of subjects, poor external validity secondary to laboratory setting, and an inability to blind subjects and testers.

Weaknesses in the majority of the research articles were related to lack of control group, extremely poor external validity, and poor internal validity. Poor study quality was expected based on the purpose of this literature review. Utilizing and comparing two assessment tools often does not allow for blinding or true controls, and is more feasible to complete utilizing a case-series study design.

**Table 2**: Articles selected from each search engine based on search strategy, inclusion, and exclusion criteria.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Search Engine | Pubmed | CINAHL | Cochrane | ERIC | PEDro | REHAB DATA | Education Full Text  |
| # of Articles Found  | 1 | 1 | 0 | 1 | 2 | 3 | 1 |

**Table 3**: Quality score, level of evidence, and study design of each selected article.

|  |  |  |  |
| --- | --- | --- | --- |
| **Author (Year)** | **Study quality score** | **Level of Evidence** | **Study design** |
| **Konop (2009)** | **Downs & Black 11/29** | **4** | **Case Series** |
| **Katz-Leurer (2010)** | **Downs & Black 16/29**  | **3B** | **Case Control**  |
| **Katz-Leurer (2009)**  | **PEDro 7/11** | **1B** | **Randomized Controlled Trial**  |
| **Fragala-Pinkham (2005)**  | **Downs & Black 14/29**  | **4** | **Case Series**  |
| **Uckun (2014)**  | **Downs & Black 11/29** | **2B** | **Cross-Sectional Design**  |
| **Smiley (2002)** | **Downs & Black 15/29**  | **4** | **Non-randomized uncontrolled repeated measures design**  |
| **Lephart (2014)** | **Downs & Black 16/29** | **4** | **Case Study**  |
| **Oriel (2008)** | **Downs & Black 18/29** | **2C** | **Outcomes Research (of exercise program)** |
| **Maltais (2004)**  | **Downs & Black 15/29**  | **3B** | **Case Control Series**  |

**Discussion**:

 Overall, the quality of evidence on the use of EEI and RPE to determine need for more supportive AD in the school system is poor. A search of seven databases yielded only 9 results. Of these nine results, only one had relevance to the school setting, and only 4 investigated the use of EEI to determine differences between ADs or orthotics16,17,18,19. An RPE scale was not utilized for either of these four most relevant studies. This could be secondary to either decreased cognition in students leading to an inability to understand the measures, a lack of knowledge of differing RPE scales for younger children, or a simple oversight/irrelevance to what the article was aiming to study. According to what is available in the research, it appears the OMNI RPE would be most appropriate for use in the school system23,16 due to it’s use of pictorials in addition to a numerical system. This would afford utilization with students who have limited literacy.

 Articles located on the EEI and use of orthotics/ADs highlight the sensitivity of the EEI to changes in gait16,17,18. There is greater evidence for use of the EEI to differentiate between ADs than for an RPE measure. Utilization of both of these measures in combination should strengthen the significance of results. Though one study investigated the effects of increased energy expenditure on fine motor skills and task completion time, no studies utilized a dependent measure of inattentiveness in class or ability to stay on task/learn – which is an important educational (aspect or goal) within the mandates of IDEA11. One previous study conducted over 20 years ago by Franks and colleagues found that AD ambulation was correlated with decreased visuomotor accuracy scores as compared to wheelchair mobility in the school setting25. The authors concluded that the results were indicative that increased energy expenditure during mobility was associated with decreased performance in the classroom. A more powerful, high quality research study could provide more consistent recommendations for use of ADs in the school population. In healthy subjects, exercise can improve cognition and decrease inattentiveness in the classroom26, 27. However, with the increase in fatigue associated with many developmental disabilities and childhood injuries – further research needs to be conducted on the effects of energy expenditure with and without ADs in children with disabilities in the school setting.

Limitations:

 Limitations to this literature review include a small sample size of articles, limitation of article inclusion based on full-PDF version availability, and low quality articles acquired via the search strategy.

Recommendations:

Research uncovered by this literature review revealed that the EEI was effective, efficient, and responsive for children of this population and age group. The EEI in combination with the RPE should be used in future research to determine the relationship between increased energy expenditure and performance in the classroom for children with developmental disabilities or debilitating injuries. It is important that appropriate measures of RPE be used for the participant population. There is a certain level of cognitive function required for each RPE scale. The Borg RPE requires a child to rate their exertion on a scale of 6-20, whereas the CERT and OMNI RPE provide a pictorial representation in addition to a descriptive sentence for children to choose from. Use of pictorials may decrease discrepancies between scoring in children with cognitive delay.

 Future research should attempt to utilize controls, have a sufficient sample size, and utilize evidence-based methods of observing student performance in the class both prior to and following ambulation with varying ADs. The addition of a behavioral assessment or learning assessment to the EEI and RPE will further outline the relationship between AD, exertion, and performance in the classroom.

**Research-Based Study Design**

 Quality research to answer the posed clinical question can be managed with minimal investment of money and time from physical therapists and teachers. Outlined below is a research protocol generated from this review which employs research-supported methods and outcome measures.

Subjects: The EEI and OMNI RPE will be used to measure the functional performance of children (aged 6-13 years old) with CP who are able to utilize two different ADs and are currently receiving school-based physical therapy (SBPT) services. For example, if a child generally utilizes a standard wheelchair, but is able to walk using a supportive walker – they would be eligible to complete the study. The population is narrowed down to children from 6-13 years old as research has demonstrated the Children’s OMNI-walk/run Scale of Perceived Exertion has the closest correlation to HR, and thus true exertion, for this population16,28.

The diagnosis of CP is utilized for this study design to improve subject recruitment given the high prevalence of CP in current school workloads and to increase internal validity of the study by not including multiple diagnoses.

Selection of participants who are currently receiving SBPT services will allow for ease of data collection from both student and teacher. Additionally, if the student is not receiving school-based physical therapy services, it is likely the question of most appropriate AD for use in the school setting is no longer an issue.

 Increasing the number of participants will improve the power and quality of the study. No previous study has sought to answer this question, therefore a case study would also contribute greatly to the body of research.

Outcome Measures:

 This study plans to utilize four outcome measures that have been established as reliable and easy to implement in school-aged children. The EEI is held as the gold standard for determining cost of ambulation in children both with and without disabilities12. Refer to page 2 for a sample calculation of EEI. Age and/or cognitive level is not a factor for this test as it is physiological and does not require participant input. For the purpose of this research, it would be best if EEI was calculated along a challenging distance the student is typically required to travel (e.g. between classes or to/from the gymnasium). For this measurement, HR will be taken after the child has been seated at rest for 5 min and HR will again be taken at the conclusion of ambulation. The therapist will measure the distance of ambulation either before or following the test and complete the EEI calculation12. Materials required for this portion of the assessment are a stop watch, tape measure, and form of HR monitor such as a pulse oximeter, chest strap, or simple palpation. EEI measurements will be taken prior to and immediately after ambulation for each AD.

 The Children’s OMNI-walk/run Scale of Perceived Exertion is a valid measurement for RPE in children aged 6-13 years old28. The OMNI scale has both pictorial and verbal descriptors to allow for children with emerging or limited literacy. There is still a cognitive component for children when completing this scale, as they must match the pictures with how they are feeling – and know why they are choosing from pictures on a paper. Therapists utilizing this scale must be able to assess the childrens’ cognitive level and determine feasibility of this measure, as no prior studies have determined a cognitive cutoff score for the assessment. Therapists should first test the child’s ability to accurately assess their RPE using a treadmill test if possible. If no treadmill is available, this test can also be completed outside on the sidewalk, on the playground, or in the hallway. If the child is able to indicate an increase in RPE with an increase in exercise intensity – this is a positive sign they are able to understand the purpose of the OMNI and generate quality results with this study. The Children’s OMNI-walk/run Scale of Perceived Exertion will be completed just prior to completion of mobility on both testing days.

 The Behavioral Observation of Students in Schools (BOSS) is an observational method of determining a child’s participation in class. The BOSS measures the following: “active engaged time, passive engaged time, off-task motor, off-task verbal, off-task passive, teacher directed instruction” (p. 457)29. The BOSS has an interobserver agreement coefficient of .93-.98 and has been able to discriminate between individuals with ADHD and their typical peers29. Though the BOSS is typically utilized in children with ADHD, it measures behavioral attention- which is the main concern of this research study.

Observers completing the BOSS require a moderate amount of training to be familiar with the technology. Approximately 10 hours should be devoted to becoming familiar with the assessment prior to use in research29. Measurements can be recorded either on paper, a computer, or through an iPhone application. A student’s activity is recorded every 15 seconds for an average time of 15 minutes29. A study by Briesch and colleagues30 found that due to variability of behavior experienced by children with disabilities, time of observation may need to be increased to as much as double – meaning a 30 minute window of observation30. If teachers are hesitant to allow observers for 30 minutes, the BOSS is set up to record observations for as little as a 5 minute time period. The BOSS would be completed by the therapist in the classroom immediately following ambulation.

 If the students’ teachers are willing, a visual analog scale (VAS) of classroom engagement may also be completed on 6 different occasions. A VAS takes minimal time to complete and thus is not a major burden on teachers. The teacher would fill out one VAS on typical student engagement in the classroom, one for current engagement in class following mobility, and one an hour following ambulation. This process would be repeated for the second AD. Fatigue levels may be greatest in the afternoon – thus if possible, testing should occur in the afternoon. The two VAS scores on typical student engagement can be utilized to determine intra-rater reliability of the measurement.

Method:

Measurements do not need to be completed on two consecutive days. If the student is receiving SBPT services twice per week, one AD can be used the first day, and the second on the second day of treatment for the week. The measurements can also be taken a week apart if necessary. It is not recommended to allow too much time between measurements to decrease external confounding factors that may attribute to a decrease in attention in the classroom. Measurements will need to be taken at least one hour before school lets out in order for the teachers to complete all 3 VAS scores and allow the therapist sufficient time to complete the BOSS.

Statistical Analysis

 A 3-way ANOVA should be completed between the EEI, OMNI, and BOSS to determine relationships between the three measurements if there are a sufficient number of participants. If there are fewer than 10 participants completing the study, a simple comparison of scores between the two devices will be completed. The VAS scores (if obtained) will be used as descriptive data for the study, as there is no research to support use of VAS in this particular patient population or for use to track attention in the classroom setting. The VAS will provide information on how the teacher viewed the child’s performance following ambulation with each AD.

Consent and Approval

 Prior to completing this study, consent forms should be formulated for parents and students. If participating students are cognitively involved, information about the study should be explained in a manner that allows for understanding of the process and what they are expected to do. Due to the nature of this study, IRB approval should also be obtained. Forms and data sheets utilized during this study should not contain identifying information in order to maintain confidentiality. No identifying information should be reported in the write-up of results. If possible, video and picture consent should also be obtained from parents/teachers.

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