
Specific Sensory Techniques and Sensory Environmental Modifications for Children and Youth With Sensory Integration Difficulties: A Systematic Review

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This systematic review examined the effectiveness of specific sensory techniques and sensory environmental modifications to improve participation of children with sensory integration (SI) difficulties. Abstracts of 11,436 articles published between January 2007 and May 2015 were examined. Studies were included if designs reflected high levels of evidence, participants demonstrated SI difficulties, and outcome measures addressed function or participation. Eight studies met inclusion criteria. Seven studies evaluated effects of specific sensory techniques for children with autism spectrum disorder (ASD) or attention deficit hyperactivity disorder: Qigong massage, weighted vests, slow swinging, and incorporation of multisensory activities into preschool routines. One study of sensory environmental modifications examined adaptations to a dental clinic for children with ASD. Strong evidence supported Qigong massage, moderate evidence supported sensory modifications to the dental care environment, and limited evidence supported weighted vests. The evidence is insufficient to draw conclusions regarding slow linear swinging and incorporation of multisensory activities into preschool settings.

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Sensory integration (SI) difficulties of children have been studied and treated by occupational therapy practitioners since the 1960s, when the term *sensory integrative dysfunction* was coined by A. Jean Ayres (1969, 1971). This term referred to children who had difficulty organizing and using sensory information to accomplish everyday activities yet did not have a medical history, intellectual disability, or a history of environmental deprivation that could account for their behavioral, learning, or motor coordination challenges (Ayres, 1972, 2005). Over subsequent decades, a variety of terms have been used to refer to this population, including *children with differences in sensory processing abilities* (Dunn, 1997) or *children with sensory processing disorders* (Miller, Anzalone, Lane, Cermak, & Osten, 2007). In this article, we refer to this population as *children with SI difficulties*.

Regardless of the term used, occupational therapy researchers have agreed that children with SI difficulties may be characterized as falling into several different subgroups, such as children with dyspraxia or children with modulation difficulties involving overreactivity. Moreover, ongoing efforts are directed toward designing interventions that will effectively help children with SI difficulties to participate more fully and successfully in everyday activities.

Prevalence estimates have suggested that a substantial number of children experience SI difficulties. Ahn, Miller, Milberger, and McIntosh (2004) estimated

that the prevalence for SI difficulties among typically developing kindergartners is about 5%. Difficulties with SI are thought to be much more common among children across a wide variety of developmental or behavioral conditions, such as autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD). For example, within the population with ASD, prevalence estimates of SI difficulties range from about 40% to more than 90% (Baranek, Little, Parham, Ausderau, & Sabatos-Devito, 2014).

Occupational therapy practitioners have historically been the leading professionals in evaluating and treating SI difficulties of children and youth. They use both remedial and compensatory intervention strategies to help children with these difficulties function better and participate more fully at home, in school, and in their communities. For example, Ayres Sensory Integration[®] (ASI) intervention is a remedial approach that is designed to improve children's SI functioning and, ultimately, their participation in daily life activities. ASI involves a course of individually administered, intensive occupational therapy sessions in which children engage in tailored activities that challenge their weak areas of SI functioning to build competencies and mastery (Ayres, 2005; Bundy, Lane, & Murray, 1991; Parham & Mailloux, 2015).

In ASI intervention, specific sensory techniques are frequently embedded within therapy sessions to support the child's performance in the immediate situation (Parham et al., 2011). For example, the therapist might introduce a slow swinging activity to calm a child who is in an overly excited state. In this example, slow rhythmic vestibular stimulation is used to reduce the child's arousal level, thereby improving attention so that the child is prepared to respond to a challenge such as timing the action of throwing a ball at a target while swinging or figuring out how to move through a novel obstacle course. Other examples of specific sensory techniques that are often embedded in ASI intervention to evoke an immediate response include providing tactile stimulation to either calm or alert the child, adding resistance to activities to enhance body awareness, or altering the speed and trajectory of a swing the child is sitting on to elicit improved postural responses.

Throughout individual ASI intervention, it is customary for the occupational therapist to regularly consult with parents, caregivers, and teachers to suggest ways in which sensory experiences can be embedded or modified in daily routines as compensatory efforts that will immediately support the child's participation (Ayres, 2005; Parham & Mailloux, 2015). This approach might include applying specific sensory techniques, such as wearing a weighted vest periodically at school, and making modifications to the child's sensory environment at home or at school by, for

example, changing the texture of dining chair seats at home or the lighting in the classroom so that the child can immediately function more optimally.

However, occupational therapy practitioners also use specific sensory techniques or sensory environmental modifications as compensatory interventions without providing ASI intervention. For example, the occupational therapist might collaborate with the teacher to have the child sit on a therapy ball while at the desk rather than a chair to generate gentle vestibular input to support attention. Although leaders in the field have advocated the use of multiple intervention methods as the most desirable approach to help children with SI difficulties (Reynolds et al., 2017), some practitioners use specific sensory techniques or sensory environmental modifications as the sole occupational therapy intervention.

Specific sensory techniques sometimes involve systematic application of sensory stimuli as stand-alone remedial interventions. For example, the Wilbarger brushing protocol (also known as the *deep pressure proprioceptive technique*) involves brushing the child's arms and legs with a surgical scrub brush using stroking motions in a particular direction and sequence, followed by manual compression of specific joints, every 2 hours (Wilbarger & Wilbarger, 1991). This protocol is thought to gradually improve the child's physiological capacity to tolerate and process tactile information, resulting in positive changes in emotion and behavior. The Astronaut Program (Kawar, Frick, & Frick, 2005) is a protocol involving a sequence of activities in which rotary and other types of vestibular input, combined with specific visual and auditory stimuli, are applied to support attention, behavior, and development of postural control.

With regard to sensory environmental modifications, occupational therapy practitioners may make compensatory changes to environments to support the successful functioning of children and youth who are not necessarily receiving ASI intervention. An example is provided by a study in which classroom modifications were made for teen students with ASD. Lighting was changed and soundproofing was installed to reduce harsh and distracting visual and auditory stimuli. These changes made the environment less disturbing and enabled students to focus on academic schoolwork more successfully and comfortably (Kinnealey et al., 2012).

This systematic review was designed to contribute knowledge that will inform occupational therapy practitioners regarding the effectiveness of specific sensory techniques and sensory environmental modifications in improving the functional performance or participation of children and youth with SI difficulties. In this article, *specific*

sensory technique is defined as the application of particular sensory stimuli, or the provision of materials and activities that provide particular types of sensory stimuli, by direct application to the child's body (such as brushing the child's arms, having the child listen to music while wearing headphones, or having the child wear compression garments) or by the child's body being placed directly on or in an object or device, such as sitting on a therapy ball or kneeling within a compression device. Specific sensory techniques may be provided as discrete protocols, as in a brushing or swinging protocol, or they may be embedded within customary daily routines at home or in school, as in sitting on a therapy ball or wearing a weighted vest in the classroom. The intent of these interventions is to support child functioning and participation through either compensation or remediation.

Sensory environmental modification is defined in this article as a compensatory intervention in which a change is made in the intensity, complexity, or quality of one or more sensory elements in the ambient physical environment surrounding the child to support child functioning and participation. Examples include alterations in room lighting, soundproofing of a room, elimination of extraneous visual stimuli in a room, or changes to the sensory features of furniture or objects in a room. Environmental changes that are introduced for primarily aesthetic, cognitive, or communication reasons, such as visual cue cards with words or pictures, are not considered sensory environmental modifications in this review. In this article, we examine specific sensory techniques and sensory environmental modifications provided outside the context of individual ASI intervention sessions.

Despite the widespread use of specific sensory techniques or sensory environmental modifications, little is known as to whether children's participation improves measurably after receiving these interventions. The purpose of this systematic review is to synthesize recent outcomes research related to the effects of these interventions on the participation of children and youth who have SI difficulties. Its specific aims are to generate information that will supplement previously published American Occupational Therapy Association (AOTA) practice guidelines for children with SI difficulties in general (Watling, Koenig, Davies, & Schaaf, 2011) and for children with ASD (Tomchek & Koenig, 2016). Children with ASD are given particular attention because SI difficulties are very common in this population (Baranek et al., 2014).

Method

This systematic review was completed under the guidance of AOTA's Evidence-Based Practice (EBP) Project, as one

in a series of several systematic reviews on diverse occupational therapy interventions for children with SI difficulties. It was designed to be an extension of a previous review on the effectiveness of occupational therapy interventions other than ASI for children and youth with SI difficulties (Polatajko & Cantin, 2010). Note that the population of interest in the earlier review, as well as in this one, includes children with concomitant diagnoses such as ASD and ADHD. The earlier review included articles published from 1986 to 2006 on outcomes of specific sensory techniques (which the authors called *sensory-based approaches*), as well as cognitive-based approaches. This review updates the earlier findings on specific sensory techniques by including articles published from 2007 through May 2015. In addition, we sought outcome studies of sensory environmental interventions because these interventions also involve applications of sensory input, but with sensory changes directed toward the physical environment surrounding the child rather than directly in contact with the child's body. Cognitive interventions were designated for a separate systematic review.

Accordingly, our Population, Intervention, Comparison, Outcomes (PICO) research question was "What is the effectiveness of occupational therapy interventions that use specific sensory techniques or sensory environmental modifications to support function and participation of children and youth who have SI difficulties?" In our question, the population of interest is children and youth (ages 2–21 yr) with SI difficulties. Two kinds of interventions are addressed: specific sensory techniques and sensory environmental modifications that are within the practice domain of occupational therapy. The comparison component of our question is an alternative condition (e.g., an alternative treatment, wait-list control, or no-treatment control). Outcomes are measures of the children's functional performance or participation.

Building on the original search strategy developed by Arbesman and Lieberman (2010), the literature search process was designed to cast a broad net that would capture articles relevant to all of the AOTA-sponsored systematic reviews of diverse SI-related interventions (ASI; cognitive, parent or teacher coaching, and occupation-based interventions; specific sensory techniques; and sensory environmental modifications) for children with SI difficulties who might also have a diagnosis such as ADHD or ASD. The original search was guided by Arbesman and Lieberman, who have had more than 10 years of experience guiding AOTA's EBP Project, and search terms were finalized after consultation with all review authors contributing to this effort. The authors of this article supplemented the primary search with additional searches using terms specific to ASD

to ensure that all articles pertinent to this population would be located. The additional ASD searches spanned 2013–2015 to build on the most recent systematic review of sensory interventions (Watling & Hauer, 2015) that informed the current occupational therapy practice guidelines for children and adolescents with ASD (Tomchek & Koenig, 2016). See Supplemental Table 1 (available online at <http://otjournal.net>; navigate to this article, and click on “Supplemental”) for search terms used to locate studies of children with SI difficulties published in 2007–2015 and Supplemental Table 2 (also available online) for search terms used to probe for additional studies of children with ASD published in 2013–2015. A medical research librarian experienced in completing systematic review searches conducted all searches.

Databases and sites searched included MEDLINE, PsycINFO, CINAHL, ERIC, and OTseeker. In addition, consolidated information sources providing peer-reviewed summaries of journal articles, such as the Cochrane Database of Systematic Reviews, were included in the search. Reference lists from articles included in the systematic reviews were examined to locate additional articles, and journals and books in the authors’ personal files were searched for appropriate research studies that met inclusion criteria.

Inclusion criteria were closely aligned with the purposes and aims of the study. Articles were included only if they were peer-reviewed scientific literature published in English. In keeping with the role of the study as part of the ongoing AOTA EBP Project, the review included only studies published between 2007 and May 2015. To be included, an article also needed to examine outcomes of a specific sensory technique or a sensory environmental modification that is within the scope of occupational therapy practice and meets our definitions of these interventions, as stated earlier in this article. To ensure that all included studies addressed our research question, additional inclusion criteria were (1) that participants had to demonstrate SI difficulties that were documented through a preintervention evaluation or through pre- and posttreatment measures of SI functioning and (2) that intervention outcomes had to include measures of participants’ functional performance or participation. Finally, studies were included in the review only if the research designs involved group comparisons, as determined by Levels I, II, and III in the evidence hierarchy delineated by the *AJOT Guidelines for Systematic Reviews* (AOTA, 2014). These levels of evidence are modeled closely after the work of Sackett, Rosenberg, Gray, Haynes, and Richardson (1996) and the *Oxford Centre for Evidence-Based Medicine—Levels of Evidence* (Howick et al., 2009). In the AOTA guidelines, studies using single-subject designs (also called *single-case experimental*

designs) were designated as Level IV and were therefore not included in this review.

Articles were excluded if they examined the outcomes of only ASI intervention or any other intervention that did not meet our definition of specific sensory technique or sensory environmental modification. They were excluded if they were not published after a formal peer-review process or if they were published before 2007 or after May 2015. We also excluded articles if the study design was Level IV or V, if SI difficulties were not clearly documented for at least one group of participants, or if outcome measures did not directly address functional performance or participation. For example, we excluded studies with outcome measures that were restricted to physiological measures, measures of SI functions, or performance on laboratory-controlled tasks.

The methodological consultant to the AOTA EBP Project completed the first step in the review process by eliminating unrelated articles on the basis of a review of article titles and citations that were generated in the database searches. Both authors then independently screened all remaining titles and abstracts to determine whether a full-text review of an article was warranted to evaluate whether the article met all inclusion criteria. In cases in which one author selected an abstract and the other did not, the article was included for full-text review. Full-text reviews were independently performed by each author to determine which articles met all inclusion criteria, with no cause for exclusion. Any disagreements were discussed in depth until a consensus was reached as to whether the article should be included in the final review.

Included studies are summarized in Supplemental Table 3 (online), which presents level of evidence, research design, intervention and control conditions, outcome measures, and results. AOTA staff and an EBP Project consultant reviewed this evidence table to ensure quality and consistency with parallel EBP-sponsored evidence reviews on interventions for children with SI difficulties (see Miller Kuhaneck & Watling, 2018; Pfeiffer, Frolek Clark, & Arbesman, 2018; and Schaaf, Dumont, Arbesman, & May-Benson, 2018, this issue).

Next, each article included in the review was further evaluated by each author independently for scientific rigor and risk of bias, using the methods described by Higgins Altman, Gøtzsche, et al. (2011; Supplemental Table 4, online). Several disagreements between authors on risk factors for individual studies were identified and resolved through discussion until a consensus was reached.

The evidence produced by the included studies was evaluated for overall strength of evidence using guidelines adapted from the U.S. Preventive Services Task Force (2016). In these guidelines, *strong evidence* indicates consistent

results from well-conducted studies, usually at least 2 randomized controlled trials (RCTs); *moderate evidence* indicates 1 RCT or 2 or more studies with lower levels of evidence; *limited evidence* indicates few studies, flaws in the available studies, and inconsistency in findings across studies; *mixed evidence* indicates that findings were inconsistent across studies in a given category; and *insufficient evidence* indicates that the number and quality of studies were too limited to make any clear classification.

Results

The initial search of the literature yielded 11,619 research studies. After the removal of 205 duplicates, we hand-searched additional resources and added 22 research studies for a total of 11,436 abstracts to be screened. After the review of abstracts, 24 research studies met initial inclusion criteria for comprehensive review (Figure 1). Using our preestablished inclusion criteria, 16 studies were excluded either because the study did not clearly indicate that participants had SI difficulties or because outcomes did not clearly measure child functional performance or participation.

Six Level I studies of specific sensory techniques met all inclusion criteria and were further analyzed (Buckle, Franzsen, & Bester, 2011; Dunbar, Carr-Hertel, Lieberman, Perez, & Ricks, 2012; Murdock, Dantzler, Walker, & Wood, 2014; Silva, Schalock, Ayres, Bunse, & Budden, 2009; Silva, Schalock, & Gabrielsen, 2011; Silva et al., 2015), as was as 1 Level II study (Silva & Schalock,

2013). Only 1 study of sensory environmental modifications (Cermak et al., 2015) met inclusion criteria. Supplemental Table 3 summarizes the included studies, which provide evidence at Levels I, II, or III for four specific sensory techniques and one environmental modification intervention: Qigong massage, weighted vests, slow linear swinging, incorporation of multisensory activities into daily preschool routines, and sensory modifications to a dental care environment. The quality of each study was further analyzed and summarized in a risk-of-bias table (Supplemental Table 4). Specific results for each intervention are summarized next.

Qigong Massage

The most robust positive outcomes, indicating strong evidence of effectiveness for young children with ASD, were found for the Qigong sensory treatment (QST), a massage protocol developed and studied by Silva and colleagues (Silva & Schalock, 2013; Silva et al., 2009, 2011, 2015). Specifically, 3 Level I studies (RCTs with N s = 46–103) and 1 Level II study (N = 129) indicated that a program of daily Qigong massage, delivered by parents to 2- to 7-yr-old children with ASD under the guidance of a trained occupational therapist, led to improvements in self-regulatory behaviors, tactile abnormalities, ASD symptoms, and parenting stress.

In 2 of the RCTs, occupational therapists received 50–60 hr of formal training in QST before initiating the QST intervention program, in which parents provided daily 15-min Qigong massage sessions to their child with ASD for 5 mo (Silva et al., 2009, 2015). During the intervention period, trainers made 20 home visits to the home of each participating family to teach parents the protocol, demonstrate how to tailor the intervention to child responses, and monitor intervention fidelity. In the third RCT (Silva et al., 2011), occupational therapists completed an 80-hr curriculum in Qigong massage skills, then trained parents in a 3-hr group instructional program to administer daily 15-min massage sessions for 4 mo. Parents also participated in seven weekly 30-min clinic-based group support meetings in which procedures were reviewed. The findings of these RCTs suggest that a minimum of 50 hr of therapist training in QST is required before teaching parents this intervention and supervising parents in administering it at home; the findings also suggest that 4 or 5 mo of daily Qigong massage with ongoing therapist supervision can be expected to produce developmental and behavior benefits for children with ASD.

Weighted Vests

Weighted vests were found to have limited evidence of effectiveness for children with ADHD. This is supported

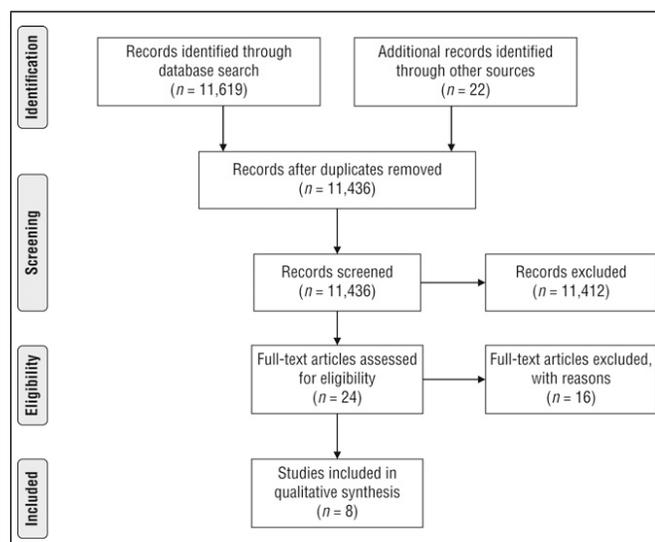


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

Figure format from “Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement,” by D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman; The PRISMA Group, 2009, *PLoS Medicine*, 6(6), e1000097. <https://doi.org/10.1371/journal.pmed.1000097>

by 1 Level I study, an RCT that demonstrated improved in-seat behavior and attention of 6- to 9-yr-olds with ADHD ($N = 30$) during classroom activities while wearing vests individually calibrated to 10% of the body weight of each child, compared with not wearing a vest (Buckle et al., 2011). Although encouraging, the results of this study must be considered with caution because of design limitations that pose threats to the internal validity of this study (see Supplemental Table 4). Our search yielded an additional RCT reporting positive effects of weighted vests on attention of children with ADHD (Lin, Lee, Chang, & Hong, 2014), but we excluded this study because the outcome measure was performance on a computerized test of attention in a laboratory environment rather than child participation within the context of the classroom.

During the search process, we identified a number of studies that used single-case experimental designs to examine the effectiveness of weighted vests worn by children with ASD (e.g., Cox, Gast, Luscre, & Ayres, 2009; Hodgetts, Magill-Evans, & Misiaszek, 2011; Leew, Stein, & Gibbard, 2010; Reichow, Barton, Sewell, Good, & Wolery, 2010), but these studies were excluded from our analysis because they were rated as Level IV evidence. In addition to this relatively low level of evidence, most of these studies did not evaluate whether participants had SI difficulties. None of these studies reported benefits of wearing a weighted vest for any participating child with ASD. Consequently, insufficient evidence is available at the present time regarding whether weighted vests are helpful for children with ASD.

Slow Linear Swinging

Vestibular stimulation in the form of slow linear swinging was examined in 1 Level I study to determine whether it produced superior on-task behavior of children with ASD ($N = 30$) during tabletop activities immediately after stimulation compared with a control condition (Murdock et al., 2014). No significant differences in on-task behavior were evident between children who experienced swinging and children in the control group, who watched a video. However, a weakness of this study is that the children's arousal state was not assessed before the intervention. Slow linear swinging is thought to promote attention by reducing arousal level to reach a calm, attentive state. This may be appropriate for children who have unusually high arousal levels that interfere with attention, but it would not be appropriate for children whose arousal levels are already low because it may make them drowsy and less attentive.

Murdock et al. (2014) reported that only 2 of the 15 participants who received linear swinging demonstrated

overresponsive behavior (suggesting high arousal), measured by parent questionnaire responses rather than assessment of the child's arousal level just before the treatment session. It is plausible that the researchers found no effect for linear swinging because most participants were in a state of low or optimal arousal at the time that they received the intervention. If this was the case, then slow linear swinging would likely have been ineffective or contraindicated for most participants in this study. We conclude that there is currently insufficient evidence for use of slow linear swinging to improve on-task behavior of children with ASD.

Sensory Enrichment in Preschool

The effects of tactile, proprioceptive, and vestibular activities embedded within preschool daily routines for 12 wk were evaluated in 1 Level I study (Dunbar et al., 2012). Preschoolers receiving this sensory enrichment intervention alone were compared with preschoolers in the same classroom who received this intervention plus individual occupational therapy using ASI intervention. After the intervention phase of the study, no difference was found between groups, both of which improved in play skills. However, this study was limited by a very small sample size ($N = 8$) and other design limitations (see Supplemental Table 4). We conclude that insufficient evidence exists to support the embedding of tactile, proprioceptive, and vestibular activities in preschool daily routines.

Other Specific Sensory Techniques

In our search, additional studies were located that examined other specific sensory techniques commonly used by occupational therapy practitioners, such as the Wilbarger brushing protocol (Benson, Beeman, Smitsky, & Provident, 2011), therapy ball chairs (Fedewa & Erwin, 2011), sensory diets (Hall & Case-Smith, 2007), and auditory stimulation programs including Therapeutic Listening (Hall & Case-Smith, 2007) and Integrated Listening Systems (Schoen, Miller, & Sullivan, 2015). These studies were not included in our review because their research designs fell at lower levels of evidence (Level IV or V), indicating significant threats to internal validity that limit the conclusions that can be drawn from them.

Sensory Environmental Modifications

Although we found only 1 study on sensory environmental modifications that met our inclusion criteria, it provided moderate evidence to support the use of sensory adaptations in the dental environment to help children with ASD participate in routine dental cleanings (Cermak

et al., 2015). This Level I RCT examined the effects of altering the auditory and visual environments of the dental office while providing the children receiving the dental cleanings with deep touch pressure via a decorative weighted wrap. Outcomes included significant improvements in child-reported measures of pain intensity and sensory discomfort, accompanied by improvements in participation in dental cleaning for both children with ASD and those who were typically developing. In addition, stress and anxiety, as measured by changes in electrodermal responses, showed a moderate to large effect size after intervention for the children with ASD ($d_s = 0.27-0.65$), suggesting that reduced physiological stress likely played an important role in improved participation.

Discussion

The availability of 3 well-designed RCTs on Qigong massage, all reporting positive outcomes, suggests that Qigong massage has strong evidence of effectiveness with preschoolers with ASD (Silva et al., 2009, 2011, 2015). It is important to bear in mind that the occupational therapists delivering this intervention had completed 50–80 hr of training before implementation. During the intervention period, they provided instruction and ongoing monitoring to parents who provided the massage on a daily basis. Caution is indicated by the fact that all of these studies were conducted by the same research group, raising the possibility that findings might not be generalizable to other groups of practitioners or to other geographic areas. Very strong confidence in this intervention would be attained if an independent research group in a different geographic region replicated these findings.

We found limited evidence in favor of the use of weighted vests to support classroom participation of children with ADHD (Buckle et al., 2011). As noted earlier, we excluded a large ($N = 110$) well-designed RCT that reported significantly positive effects of weighted vests on attention of children with ADHD because the outcome measure was performance on controlled laboratory tasks rather than functional performance in the classroom (Lin et al., 2014). However, when considered together, these 2 studies suggest that perhaps the deep touch pressure of the vest supports the ability of children with ADHD to attend to cognitive tasks, thereby helping them to engage in classroom activities at school. Future research is necessary to test this proposition and to evaluate whether weighted vests can be confidently used to support the participation of children with ADHD in classroom activities.

Note that this evidence suggesting the effectiveness of weighted vests applies only to children with ADHD, not

children with ASD. Large, well-designed studies that provide Level I evidence would be helpful in evaluating whether weighted vests are helpful for children with ASD. Given the limited evidence available and the fact that this limited research generally has not found that these children benefit from wearing weighted vests, we do not currently recommend this intervention for children with ASD.

Our review found insufficient evidence for the effectiveness of slow linear swinging in producing improved on-task behavior of children with ASD. This intervention was not effective in a Level I study (Murdock et al., 2014), but a flaw of this study is that the arousal state of each participant was not assessed before intervention. As noted earlier, slow linear swinging may be appropriate for children who have unusually high arousal levels that interfere with attention. Past research has shown that children with ASD demonstrate divergent levels of baseline physiological arousal; some children have unusually high arousal, and others have unusually low arousal (Chang et al., 2012; Schoen, Miller, Brett-Green, & Hepburn, 2008). Moreover, some children with ASD may fluctuate from very low to very high states of arousal. Because this population is heterogeneous with regard to baseline arousal states, it is plausible that vestibular stimulation interventions may be effective if they are tailored to the individual child's arousal state before stimulation is applied. Future research is needed to examine this possibility.

We also found insufficient evidence for incorporating specific sensory techniques into daily preschool class routines for children with ASD. Because the 1 study we analyzed (Dunbar et al., 2012) was a very small study and both study groups received the same regimen of sensory techniques within the classroom, it is unclear whether improvements in play skills were due to developmental gains that would have been observed regardless of the addition of this intervention. It may be useful for future researchers to further examine the effectiveness of embedding specific sensory techniques into preschool routines. For example, comparison of this intervention with standard classroom routines (i.e., without the addition of specific sensory techniques) might clarify whether the addition of this intervention promotes developmental gains that surpass the usual benefits of being in preschool.

Although we found only 1 study on sensory environmental modifications that met our inclusion criteria, it provided moderate evidence to support the use of sensory adaptations in the dental environment to help children with ASD participate in routine dental cleanings (Cermak et al., 2015). The intervention in this RCT incorporated a specially designed weighted blanket in

addition to changes in the ambient auditory and visual environment of the dental clinic, so it is possible that use of deep-touch pressure as a sensory technique contributed to the effectiveness of the intervention. Further research would be helpful in strengthening confidence in the effectiveness of this intervention.

In this review, we included only studies with high levels of evidence in which the researchers had verified that participants had SI difficulties and reported outcomes reflecting functional performance or participation. These inclusion criteria contributed to the small number of studies included in this systematic review. It is noteworthy that we were unable to locate any published studies at any level of evidence that examined the effectiveness of some specific sensory techniques, for example the Astronaut Program (Kawar et al., 2005). It should be borne in mind that the absence of evidence does not indicate absence of effectiveness (Altman & Bland, 1995); however, without strong evidence to support a particular intervention, we have limited confidence that the intervention can be counted on to produce the desired outcomes.

Our review was intentionally delimited to studies that met stringent inclusion criteria, that is, limited range of publication dates, high levels of evidence, participants with verified SI difficulties, particular kinds of sensory interventions, and outcomes that are functional. This was necessary to meet the purpose and specific aims of the study. However, a limitation of our systematic review is that we may not have included some search terms that could have produced eligible studies. We attempted to generate an exhaustive list of search terms, as shown in Supplemental Tables 1 and 2, but perhaps discrete terms such as *touch* or *tactile*, or alternative terms such as *therapy ball* in addition to *ball chair*, would have generated abstracts that our search did not detect. As with all systematic reviews, reliance on published peer-reviewed studies raises the possibility that publication bias could have influenced our conclusions.

Implications for Occupational Therapy Research

The results of our systematic review revealed several issues that researchers should address to improve the quality of future studies of the effects of specific sensory techniques or sensory environmental modifications on the participation of children with SI difficulties. First, the strongest research design that is feasible should be used to evaluate the effectiveness of these interventions. Most of the published studies of these interventions used research designs with relatively low levels of evidence, which severely limits confidence in the findings.

Second, researchers should articulate the underlying mechanism for why the intervention being studied is expected to enhance child participation. For example, slow linear swinging usually reduces arousal level and is therefore expected to have a calming effect that may support sustained attention in children with heightened arousal. It would be helpful to design studies in which the outcome measures are aligned with the underlying mechanism of the treatment (e.g., decrease in arousal level after slow linear swinging) as well as the primary participation outcome (e.g., improved sustained attention during classroom activities). This would allow researchers to test the underlying theory of why the intervention is thought to be helpful, as well as the intervention's effectiveness in supporting child participation. Research results will ultimately lead to deeper understanding of the conditions under which a particular intervention is or is not effective in supporting participation. Once the underlying mechanism is better understood, the inclusion or exclusion criteria for future study participants can be tailored to ensure that only children who are appropriate candidates for the intervention are eligible to participate.

To our knowledge, no studies of specific sensory techniques or sensory environmental modifications have reported on adverse events associated with the intervention. Although such events are probably rare, they should be systematically documented and reported in research publications because this information could be a critical factor in clinical decision making. Cost-benefit analyses comparing these interventions with alternative procedures would also contribute valuable information for decision making.

Implications for Occupational Therapy Practice

Our review highlights several important considerations for occupational therapy practitioners. First, for practitioners to best implement specific sensory interventions or sensory environmental modifications, postprofessional training in SI is strongly recommended. This training will ensure that practitioners have an adequate knowledge base for evaluating and selecting children who are good candidates for particular interventions and for monitoring child responses to intervention. To ascertain whether a child's sensory characteristics make him or her a good candidate for particular interventions, evaluation of SI should be completed prior to initiating any sensory intervention. It is incumbent on the practitioner to use caution when considering an intervention that has limited or no research evidence; such interventions should be used only after considering interventions with stronger evidence

that may be appropriate for the particular situation. Regular monitoring of child responses to intervention is imperative to ensure that the intervention is benefiting the child and to avoid undesirable effects. Additional recommendations specific to the five interventions identified in this study are as follows:

- Preschoolers with ASD and tactile overreactivity may be particularly appropriate for Qigong massage, which has moderate to strong evidence to support its effectiveness when provided as QST.
- The evidence for the effectiveness of weighted vests with children with ADHD is limited, and it is insufficient for children with ASD. Occupational therapy practitioners should cautiously consider using weighted vests to support attention in the classroom for elementary school-age children with ADHD.
- The evidence for slow linear swinging is insufficient with respect to immediate effects on attention. Occupational therapy practitioners should not expect that slow linear swinging will immediately improve attention of preschoolers with ASD during tabletop activities.
- Insufficient evidence supports the effectiveness of regularly incorporating specific sensory techniques into classroom routines for preschoolers with ASD, so occupational therapy practitioners should consider the use of this intervention cautiously.
- Moderate evidence supports sensory modifications to the dental care environment. Occupational therapy practitioners who serve children with ASD should consider collaborating with dental professionals to explore using this new intervention. ▲

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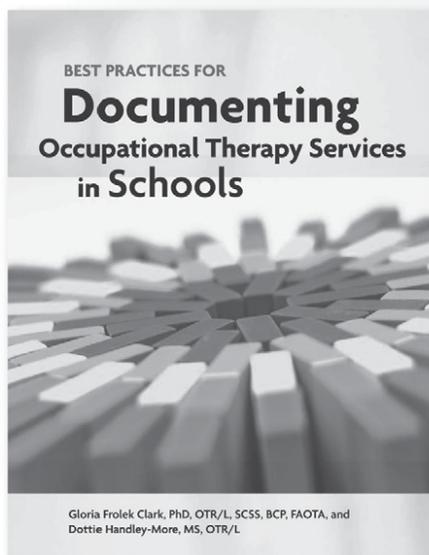
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