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REVIEW PAPER

Measurement Tools to Assess Usual Dietary Intake and Physical Activity in Individuals with Autism Spectrum Disorder: a Scoping Review

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Abstract

This review aimed to identify measurement tools to assess dietary intake and physical activity (PA) among individuals with autism spectrum disorder (ASD) and describe the evidence of validity and availability of each tool. Searches were conducted in PubMed, Embase, CINAHL, and PsycINFO using keywords for ASD, PA, diet, and assessment/measurement ($n = 2364$ articles). After removing duplicates and title/abstract screening, 212 full-text articles were reviewed, and 113 articles were included for data extraction. The most common dietary and PA assessment tools were identified, and each reviewer independently extracted the data on target population of the assessment tool, type of instrument, evidence on psychometrics validation, constructs measured, and instrument availability. Our findings highlight the need for instruments developed for and/or validated in this population.

Keywords Diet · Physical activity · Lifestyle behaviors · Assessment · Autism spectrum disorder · Measurement tool

Autism spectrum disorder (ASD) is one of the most common developmental disorders, affecting one in 44 children in the USA (Maenner et al., 2021). In addition to persistent impairments in social interaction and restrictive behaviors (Maenner et al., 2021), individuals with ASD are likely to develop chronic non-communicable diseases such as obesity, hypertension, and dyslipidemia (Dhaliwal et al., 2019; Goldstein & Korczak, 2020; WHO, 2019). For example, youth with ASD have 41.1% greater risk of developing obesity compared to typically developing youth (Kahathuduwa et al., 2019), which is concerning because children who are obese are more likely to become obese as adults as well as have chronic diseases such as cardiovascular disease, type 2 diabetes, and cancer (Llewellyn et al., 2016). Lifestyle risk factors including poor dietary habits and lack of physical activity (PA) contribute to the increased risk of chronic diseases. Youth with ASD are more predisposed to problematic eating behaviors such as food selectivity, less likely to meet PA guidelines, and more likely to spend extra time watching television compared to typically developing children (Ketcheson & Pitchford, 2021; McCoy & Morgan, 2020; Sharp et al., 2013).

While many studies have assessed eating and PA behaviors in individuals with ASD (Kral et al., 2013; Liang et al.,

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2020), validity, reliability, or psychometric properties of those assessment tools have been rarely reported, and there have been no clear guidelines for choosing appropriate tools to assess usual dietary intakes and PA behaviors among populations with ASD (McClung et al., 2018). It is also unclear whether each assessment tool used in previous studies is justified to be used among individuals with ASD and which methods are selected for different study designs, purposes, age groups, and outcome types. Given that the primary characteristics of ASD are having limited communication and social skills, youth with ASD may experience more challenges in self-reporting their eating and PA behaviors compared to typically developing youth. Repetitive behaviors and narrow interests may also affect their ability to accurately answer food or PA behavior questions and to finish assessment in the allotted time. For example, PA questionnaires used in neurotypical individuals may have difficulty characterizing the PA of an individual with ASD who engages in repetitive motor behaviors or short intermittent bouts of PA. In addition, about 35% of children with ASD are reported to have intellectual disability (Maenner et al., 2021), which increases potential challenges to conduct eating and PA assessment in this population. Therefore, individuals with ASD may require assistance to complete a questionnaire that is intended to be self-report. Due to these challenges, direct behavior observations (e.g., counting number of food bites or engagement in a certain movement) such as functional analysis have been used. However, even though direct observation is ideal for assessing short-term functional behaviors of individuals or a small group of youth with ASD, because it could be time-consuming and labor-intensive to directly observe usual dietary intake and PA behaviors of a large sample of children or adolescents, it has not been frequently used in previous studies that included moderate to large sample sizes.

While direct measures of energy intake and expenditure such as whole room calorimetry and double labeled water (DLW) method are considered the most accurate, these methods are costly and may not capture real-life amounts of dietary intake and PA (Burrows et al., 2019; Phillips et al., 2021; Westerterp, 2017). Therefore, dietary intake is often assessed with self-report measures such as food records, 24-h dietary recalls, and food frequency questionnaires (FFQs) (McClung et al., 2018). The food record is an open-ended method that requires the participant to write down all foods and beverages consumed at the time of consumption, and the 24-h dietary recall is an open-ended method where an interviewer asks the respondent to recall and report all the foods and beverages consumed in the preceding 24 h (Slimani et al., 2015). The FFQ is a closed questionnaire method that asks participants about their frequency of consumption of a list of food and beverage items (often together with portion size options) over a specified time period such as per week, month, or year (Slimani et al., 2015). Research studies have shown that different dietary assessment tools pose under- or over-reported intake based on the characteristics of the subjects (e.g., individuals with obesity) and inevitability for bias (e.g., social desirability bias). However, self-report dietary measures are useful for estimating usual intakes of food groups, densities, varieties, and nutrients to inform nutrition intervention or policy development and to assess associations between eating behaviors and disease outcomes (Subar et al., 2015). PA can be assessed using proxy report measures, device-based measurements, and direct observation or measures of energy expenditure (Phillips et al., 2021). Limitations of PA assessments in children include difficulty recalling PA behaviors due to cognitive capabilities and increased possibility that children will attempt to play with the device in a way that may render its results less effective (Phillips et al., 2021). In addition, the tendency for irregular and intermittent behavior, especially in young children, can add to the difficulty of measuring PA (Phillips et al., 2021).

A scoping review is a useful methodology for providing an overview of the available research evidence to answer broad questions (Sucharew & Macaluso, 2019), and has been used to identify the breadth of assessment tools (Yee et al., 2017). The purpose of this scoping review was to examine measurement tools that assess usual dietary intakes and PA behaviors among individuals with ASD and make recommendations for future research. Objectives included the following: (1) to identify and summarize existing dietary intake and PA assessment tools used in individuals with ASD based on study designs and sample characteristics (i.e., country, sample size, percent male, and age) and (2) to describe the evidence of validity and availability of each measurement tool.

Methods

Study Selection Process

The literature was searched using the databases PubMed, Embase (Elsevier), CINAHL (EBSCO), and PsycINFO (EBSCO) in August 2020. Another search was conducted in February 2022 to include the latest research studies published between August 2020 and December 2022. A search strategy was developed combining the main concepts and related terms for autism spectrum disorders and PA or dietary behaviors and assessment/measurement (see the Supplementary material for the full search strategies). Inclusion criteria were as follows: (1) utilized a dietary or PA assessment, (2) included individuals with ASD, (3) published in a peer reviewed journal, (4) written in English language. Exclusion criteria included review articles, case studies, or other types that are not research articles such as newsletters and commentaries, written in non-English language, and

studies that combined intellectual or developmental disability (IDD) without distinguishing samples with ASD. Studies that examined special diet interventions such as gluten free and casein free diet (GFCF) for individuals with ASD were further excluded because several review and meta-analysis studies have been recently conducted on special diets for ASD (Bjorklund et al., 2020; Keller et al., 2021; Piwowarczyk et al., 2018; Quan et al., 2021). Databases were selected and search strategies were developed by JMH, JT, HLG, AWB, and AMH. The review team consisted of experts in PA (JMH, JT), nutrition and dietary assessment (HLG, AWB), and a student research assistant (RS). Each reviewer independently screened the results and applied the inclusion/exclusion criteria. Any discrepancies were discussed among the review members and resolved until complete agreement was reached by the entire review team. A health sciences librarian (AMH) assisted in developing the search strategies but was not involved in the screening process.

The PRISMA flow diagram shows results of the database searches and study selection process (Fig. 1). There were 2364 total articles identified from the initial search. After removing duplicates and records not meeting the inclusion criteria, 1990 were included for the title and abstract review. JMH, JT, HLG, AWB, and RS participated in the full-text review, which included 212 full-text articles. After excluding 99 articles from the full-text review, 113 articles were included for the final review and data extraction. There were 109 studies that examined either dietary intake only ($n=66$) or PA only ($n=43$), and four studies examined both dietary intake and PA behaviors.

Data Extraction

Data were extracted by two reviewers who are experts in PA (JMH, JT) and two who are experts in nutrition and diet (HLG, AWB). JMH and JT extracted and double-coded data from the articles that measured PA behaviors, and HLG and AWB did the same for the articles that assessed dietary intake. Each reviewer independently extracted the following data from each article within their specialty: location/country, study design, sample size, percent male, age range, diet or PA assessment tool, target population of the assessment tool, type of instrument, evidence on psychometrics validation, and constructs measured. The availability of the

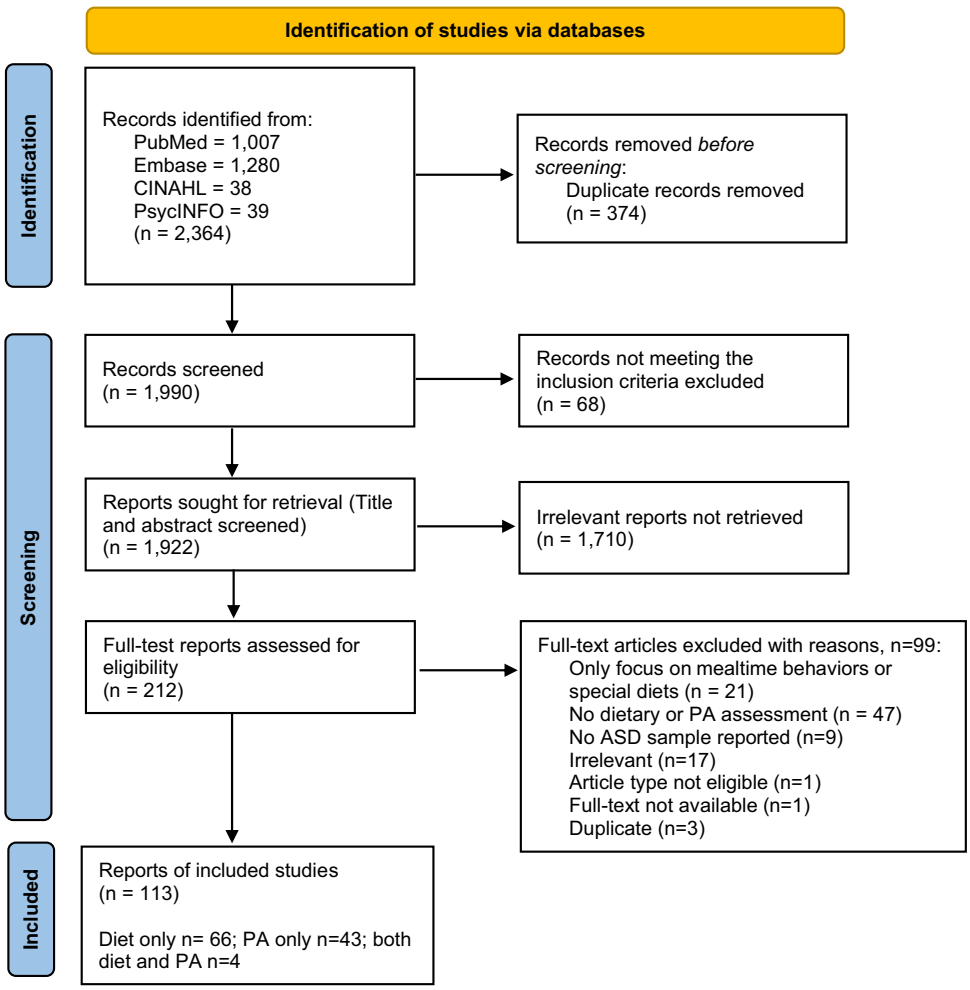

Fig. 1 PRISMA 2020 flow diagram

instrument tool was further determined. Double-coded data by two reviewers were compared and any discrepancies were discussed and resolved until the group reached consensus.

Results

Study Characteristics

Table 1 summarizes the characteristics of the studies reviewed, including the country where the study was conducted, study design, sample size, percent male, and age of the participants. The majority of the studies identified were published after 2015, and only two articles were published prior to 2000 (Cornish, 1998; Raiten & Massaro, 1986). Studies were conducted across 29 countries with sample sizes of participants with ASD ranging from 3 (Becerra et al., 2021) to 95,744 (Dennison et al., 2021). Over half of the studies used a cross-sectional design ($n=65$); 34 studies used a case control; 4 studies used a longitudinal observation; 5 studies used a pre-post intervention; and 2 studies used a randomized controlled trial study design. Other study designs included a non-randomized controlled trial ($n=1$); a quasi-experimental trial ($n=1$); a retrospective chart review ($n=1$); and a single subject design ($n=1$). Age ranges varied, but most studies included children and adolescents aged 2–18 years. Some studies included youth up to 21 years and 8 studies only included young adult and adult participants (ages 18–79 years). Males made up the majority of participants in most studies (> 50%). Thirteen studies had 100% male participants.

Dietary Intake Assessments

24-h Dietary Recall or Multiple-Day Food Records

Most studies that measured dietary intake used a single 24-h recall or multiple-day food records. There were some variations in the number of days in dietary recalls and food records: four studies used a 24-h dietary recall (Bicer & Alsaffar, 2016; Johnson et al., 2008; Panossian et al., 2021; Padmanabhan & Shroff, 2020; Moorthy et al., 2021) and the majority of the studies that used food records collected 3 days of dietary intakes including 2 weekdays and 1 weekend day (Attlee et al., 2015; Bandini et al., 2019; Berding & Donovan, 2018, 2020; Bicer & Alsaffar, 2013; Castro et al., 2016; Graf-Myles et al., 2013; Hamlin et al., 2013; Herndon et al., 2009; Hyman et al., 2012; Marí-Bauset et al., 2015b; Marí-Bauset et al., 2015a; Marí-Bauset et al., 2016a, 2016b; Marí-Bauset et al., 2017; Marshall et al., 2015, 2016; Meguid et al., 2015; Meguid et al., 2017; Neumeyer et al., 2013, 2017a, b, 2018; Reynolds et al., 2012; Sharp et al., 2011; Sharp et al., 2018; Shmaya et al., 2015; Siddiqi et al., 2019; Soden et al., 2012; Stewart et al., 2015; Sun et al., 2013; Tanoue et al., 2017; Xia et al., 2010; Buro et al., 2022; Eow et al., 2021; Plaza-Diaz et al., 2021; Yeung et al., 2021; Molina-López et al., 2021; Siddiqi & Urooj, 2022; Zeybek & Yurttagul, 2020; Alkhalidy et al., 2021). One study collected 2-day food records (Liu et al., 2016) and another study collected 7-day diet records (Raiten & Massaro, 1986). All studies using dietary recalls and food records analyzed nutrients, food groups, food variety, or diet quality. Multiple dietary recalls and 3-day food records have been considered appropriate tools to estimate usual intake of individuals and dietary patterns or trends of general population (Shim et al., 2014; Thompson & Subar, 2017). Validity of 24-h dietary recalls was examined in 1977 (Graham, 1977) and the 3-day food record method was validated in 1987 (Krall & Dwyer, 1987), and both methods have been standardized and used in numerous studies.

Participants in the studies that used 24-h recalls or food records ranged from young children (< 5 years) to 20 years, and sample size ranged 3–811, but parents completed recalls and food records on behalf of their children in most studies. In one study, older children assisted in completing 3-day food records for foods consumed outside the home (Bicer & Alsaffar, 2013), and in another study, children were present during the 24-h recall interview (Bicer & Alsaffar, 2016). Three-day food records were used for up to 367 children with ASD, and studies with a sample size larger than 400 used a single 24-h recall.

Food Frequency Questionnaire

The second most commonly used dietary assessment tool was the Food Frequency Questionnaire (FFQ), including the Block FFQ (Al-Farsi et al., 2013b; Matheson et al., 2019), Youth Adolescent Food Frequency Questionnaire or YAQ (Bandini et al., 2019; Berding & Donovan, 2018, 2020; Evans et al., 2012; Hubbard et al., 2014), Brief self-administered Dietary History Questionnaire or BDHQ (Tsujiguchi et al., 2020), Shizuoka FFQ (Nakamura et al., 2019), an omega-3 specific FFQ (Ferguson et al., 2019), a food frequency checklist (Cornish, 1998), a FFQ adapted from Mind, Exercise, Nutrition…Do It! (MEND) Questionnaire (Hinckson et al., 2013), a FFQ adapted from the Willett FFQ (Raspini et al., 2021), and other variations of the FFQ (Al-Farsi et al., 2013b; Diolordi et al., 2014; Emond et al., 2010; Ferguson et al., 2019; Hinckson et al., 2013; Johnson et al., 2008; Leiva-García et al., 2019; Lindsay et al., 2006; Ma et al., 2019; Meguid et al., 2017; Yeung et al., 2021). The FFQs asked about intake over a 1 week to a year. FFQ data were used to measure nutrients, food groups, and food variety. Target population, type of instrument, evidence of psychometrics/validity, constructs

Table 1 Summary of study design and sample characteristics

First author, year	Country	Study design	Sample size	Percent male (%)	Age (years)
Al-Farsi et al., 2013a	Oman	CC	80 (ASD 40; C 40)	N/A	4.1 [m]
Al-Farsi et al., 2013b	Oman	CC	80 (ASD 40; C 40)	50	3–5
Alkhalidy et al., 2021	Jordan	CC	103 (ASD 53; C 51)	61	3–6
An et al., 2019	USA	PPI	14 (IDD including ASD)	64	12–15
Attlee et al., 2015	UAE	CS	23 (ASD)	78	5–16
Bandini et al., 2013	USA	CS	111 (ASD 53; C 58)	80	3–11
Bandini et al., 2019	USA	CC	56 (IDD including ASD)	68	3–8
Becerra et al., 2021	Ireland	SSD	3 (ASD)	33	4
Berding and Donovan, 2018	USA	CC	58 (ASD 26; C 32)	ASD 73; C 59	2–7
Berding and Donovan, 2020	USA	LO	58 (ASD 26; C 32)	ASD: 73; C 59	2–7
Bicer and Alsaffar, 2013	Turkey	CS	164 (ASD)	81	4–18
Bicer and Alsaffar, 2016	Turkey	CS	216 (ASD 118; C 97)	100	12–18
Boddy et al., 2015	UK	CS	70 (ASD 17; C 53)	81	5–15
Borremans et al., 2010	Finland	CS	30 (ASD)	70	15–21
Brown et al., 2020	Canada	CS	201 (ASD 161; C 40)	100	4–17
Buro et al., 2022	USA	PPI	12 (ASD)	67	8–19
Canals-Sans et al., 2022	Spain	CC	451 (ASD 77; Subclinical ASD 40; C 333)	63	3–12
Castro et al., 2016	Brazil	CC	98 (ASD 49; C 49)	100	4–16
Chu et al., 2020	Taiwan	CS	63 (ASD)	100	12–18
Cornish, 1998	England	CS	17 (ASD)	N/A	4–10
Dahlgren et al., 2021	Ireland	LO	176 (ASD 88; C 88)	78	9–18
Dennison et al., 2021	UK	CS	95,744 (ASD)	44	40–69
Diolordi et al., 2014	Italy	CC	68 (ASD 33; C 35)	ASD 82; C 49	2–9
Emond et al., 2010	England	CC	12,980 (ASD 29; C 12,901)	N/A	0.5
Eow et al., 2021	Malaysia	CS	224 (ASD)	83	3–7
Esenturk & Yarımkaya, 2021	Turkey	non-RCT	14 (ASD)	57	9–14
Evans et al., 2012	USA	CC	111 (ASD 53; C 58)	ASD 83; C 78	3–11
Ferguson et al., 2019	USA	CS	120 (ASD)	90	6–18
Garcia et al., 2020	USA	CS	49 (ASD)	100	8–17
Garcia-Pastor et al., 2019	Spain	CS	68 (ASD)	42	7–48
Graf-Myles et al., 2013	USA	CC	120 (ASD 69; IDD14; C 37)	N/A	1–6
Haegele et al., 2021	USA	CS	36 (ASD 18; C 18)	14	13–18
Hamlin et al., 2013	USA	CS	288 (ASD)	N/A	2–11
Hamm and Yun, 2019	USA	CS	281 (ASD 143; C 138)	43	18–35
Healy et al., 2021	USA	CS	361 (ASD)	60	18–50
Heffernan et al., 2018	USA	CS	15 (ASD)	87	7 [m]
Herndon et al., 2009	USA	CC	77 (ASD 46; C 31)	ASD 96; C 74	1–8
Hillier et al., 2020	USA	CS	60 (ASD 30; C 30)	90	18–28
Hinckson et al., 2013	New Zealand	PPI	22 (ASD)	59	8–20
Hubbard et al., 2014	USA	CC	111 (ASD 53; C 58)	ASD 83; C 78	3–11
Hyman et al., 2012	USA	CC	367 (ASD)	N/A	2–11
Johnson et al., 2008	USA	CC	34 (ASD 19; C 15)	N/A	2–4
Ketcheson et al., 2017	USA	QE	20 (ASD)	75	4–6
Ketcheson et al., 2018	USA	CS	53 (ASD 34; C 19)	66	2–5
Kotha et al., 2018	Saudi Arabia	CS	N/A	N/A	6 [m]
Leiva-García et al., 2019	Spain	CS	146 (ASD 55; C 91)	ASD 74; C 54	6–18
Lindsay et al., 2006	USA	RCT	20 (ASD)	95	5–13
Liu et al., 2016	China	CC	227 (ASD 154; C 73)	92	5 [m]
Lobenius-Palmér et al., 2018	Sweden	CS	102 (ASD 25; C 77)	57	7–20

Table 1 (continued)

First author, year	Country	Study design	Sample size	Percent male (%)	Age (years)
Ma et al., 2019	China	CC	90 (ASD 45; C 45)	87	6–9
Malhi et al., 2017	India	CC	113 (ASD 63; C 50)	91	4–10
Mangerud et al., 2014	Norway	CS	566 (ASD 39; C 527)	46	13–18
Marí-Bauset et al., 2015a	Spain	CC	153 (ASD 40; C 113)	87	6–10
Marí-Bauset et al., 2015b	Spain	CC	600 (ASD 105; C 495)	ASD 89; C 54	6–9
Marí-Bauset et al., 2016a	Spain	CC	600 (ASD 105; C 495)	ASD 89; C 54	6–9
Marí-Bauset et al., 2016b	Spain	CC	600 (ASD 105; C 495)	ASD 89; C 54	6–9
Marí-Bauset et al., 2017	Spain	CC	600 (ASD 105; C 495)	ASD 89; C 54	6–9
Marshall et al., 2015	Australia	RCT	68 (ASD 36; C 32)	74	2–6
Marshall et al., 2016	Australia	CC	68 (ASD 33; C 35)	ASD 76; C 71	2–6
Matheson et al., 2019	USA	PPI	20 (ASD)	90	5–14
Meguid et al., 2015	Egypt	CS	80 (ASD)	51	3–9
Meguid et al., 2017	Egypt	CC	160 (ASD 80; C 80)	ASD 79; C 78	4–6
Memari et al., 2013	Iran	CS	80 (ASD)	65	7–12
Memari et al., 2017	Iran	CS	68 (ASD)	62	6–16
Molina-López et al., 2021	Spain	CC	144 (ASD 55; C 91)	N/A	6–18
Moorthy et al., 2021	India	CC	272 (ASD 136; C 136)	71	5–12
Nakamura et al., 2019	Japan	CS	2,053 (ASD)	70	18–79
Neumeyer et al., 2013	USA	CS	37 (ASD 18; C 19)	100	8–14
Neumeyer et al., 2017a	USA	CS	34 (ASD 16; C 18)	100	9–18
Neumeyer et al., 2017b	USA	LO	49 (ASD 25; C 24)	100	8–17
Neumeyer et al., 2018	USA	CS	49 (ASD 25; C 24)	100	8–17
Neville et al., 2021	N/A	CS	118 (ASD)	74	24–39 months
Nguyen et al., 2021	France	CS	50 (ASD)	100	7–17
Kamal Nor et al., 2019	Malasyia	CS	151 (ASD)	87	2–18
Ogino et al., 2018	Japan	CS	27 (ASD 15; C 13)	85	7–16
Oreskovic et al., 2020	USA	PPI (+FU)	21 (ASD)	67	6–10
Otsuki and Ohashi, 2014	Japan	CS	26 (ASD 7; C 19)	N/A	18 [m]
Padmanabhan and Shroff, 2020	India	CS	146 (ASD)	81	3–11
Pan, 2008a	Taiwan	CS	48 (ASD 24; C 24)	96	7–12
Pan, 2008b	Taiwan	CS	48 (ASD 24; C 24)	96	7–12
Pan and Frey, 2006	USA	CS	30 (ASD)	90	10–19
Pan et al., 2015	Taiwan	CS	60 (ASD 30; C 30)	100	12–17
Pan et al., 2016	Taiwan	CS	70 (ASD 35; C 35)	100	12–17
Pan et al., 2021	Taiwan	CS	68 (ASD)	100	6–17
Panossian et al., 2021	Australia	LO	811 (ASD)	49	At 1, 2, 3, 20
Plaza-Diaz et al., 2021	Spain	CC	111 (ASD 54; 57 C)	ASD 83; C 75	2–6
Raiten and Massaro, 1986	USA	CC	74 (ASD 40; C 34)	ASD 70; C 56	ASD 11; C 9 [m]
Raspini et al., 2021	Italy	CC	147 (ASD 65; C 82)	88	1–6
Reynolds et al., 2012	USA	CS	222 (ASD)	87	2–11
Sahlander et al., 2008	Sweden	CS	44 (ASD 15; C 29)	18	21–35
Sandt and Frey, 2005	USA	CS	28 (ASD 15; C 13)	64	5–12
Şengüzel et al., 2021	Turkey	CS	46 (ASD)	83	2–10
Sharp et al., 2011	USA	RCR	13 (ASD)	85	2–7
Sharp et al., 2018	USA	CS	70 (ASD)	80	2–17
Shmaya et al., 2015	Israel	CC	91 (ASD 50; S 12; C 29)	ASD 80; S 71; C 76	3–6
Siddiqi et al., 2019	India	CS	53 (ASD)	85	2–13
Siddiqi and Urooj, 2022	India	CS	104 (ASD)	79	2–15
Soden et al., 2012	USA	CS	26 (ASD)	N/A	10–18
Stanish et al., 2017	USA	CS	95 (ASD 35; C 60)	72	13–21

Table 1 (continued)

First author, year	Country	Study design	Sample size	Percent male (%)	Age (years)
Stewart et al., 2015	USA	CS	288 (ASD)	86	2–11
Sun et al., 2013	China	CC	106 (ASD 53; C 53)	85	4–6
Sung et al., 2021	Taiwan	CS	53 (ASD 25; C 28)	84	48–72 months
Tanoue et al., 2017	Japan	CS	28 (ASD)	92	5–27
Tomaszewski et al., 2022	USA	CS	38 (ASD)	71.1	18–55
Tsujiguchi et al., 2020	Japan	CS	1,108 (ASD)	48	7–15
Tyler et al., 2014	USA	CS	29 (ASD 17; C 12)	52	10–17
Wachob and Lorenzi, 2015	USA	CS	10 (ASD)	N/A	9–16
Weir et al., 2021	UK	CS	2386 (ASD 1183; C 1203)	ASD 37; C 31	ASD 41; C 42 [m]
Xia et al., 2010	China	CS	111 (ASD)	N/A	2–9
Yeung et al., 2021	China	CC	130 (ASD 65; C 65)	83	3–6
Zeybek and Yurttagul, 2020	Cyprus	CS	40 (ASD)	83	N/A
Zhu et al., 2020	China	CS	1040 (ASD 738; C 302)	ASD 85; C 50	2–6
Zurita, 2020	Ecuador	CC	60 (ASD 25; C 35)	ASD 96; C 92	5–12

ASD, autism spectrum disorder; *C*, control; *CC*, case control; *CS*, cross-sectional; *PPI*, pre-post intervention; *LO*, longitudinal observational; *QE*, quasi-experimental; *FU*, follow-up; *RCR*, retrospective chart review; *SSD*, single subject design; *non-RCT*, non-randomized controlled trial; *N/A*, not available; *m*, mean age; *IDD*, intellectual and developmental disability

measured, references, and availability of the instruments used in FFQ studies are summarized in Table 2.

Parents completed the Block FFQ, YAQ, BDHQ, the Willett FFQ, and food frequency checklist for their children. For other FFQs, parent or self-report was used. In one study, children aged 7–15 years assisted their parents as appropriate (Tsujiguchi et al., 2020). Two studies reported that the FFQ was completed by a parent caregiver or by the participant (Ferguson et al., 2019; Leiva-García et al., 2019). Another study with adult participants aged 18–79 years used self-report (Nakamura et al., 2019).

Evidence on psychometrics of the instruments varied by different FFQs. The Block questionnaires have multiple versions such as a full-length, a brief, or Block Kids FFQ (Block et al., 1986; Cullen et al., 2008; Harlan & Block, 1990). Two studies in this review utilized a full-length Block FFQ or a 60-item brief Block FFQ, and both were completed by the parents of children with ASD (Al-Farsi et al., 2013b; Matheson et al., 2019). The study describing the development and validation of the full-length Block FFQ showed strong correlation coefficients between the FFQ and a diet record for all nutrients, which ranged from 0.73 to 0.94 (Block et al., 1986). The brief Block FFQ was validated against the full Block FFQ resulting in high correlation coefficients (> 0.90) for all nutrients, and when it was compared with dietary records data from 7-day food records, having a reduced number of food items (34, 15, 10) yielded correlation coefficients greater than 0.70 (Block et al., 1990).

The YAQ has been validated against multiple 24-h recalls with moderate correlations (Rockett et al., 1997) and test–retest reliability results indicated moderate reproducibility in children and adolescents ages 9–18 years (Rockett et al., 1995). The authors concluded that the YAQ has a reasonable ability to assess dietary intake and habits of children and adolescents (Rockett et al., 1995, 1997).

BDHQ-10y and BDHQ-15y were adapted and modified from an adult BDHQ for Japanese children and adolescents. Validity of the questionnaires was examined against biomarkers such as serum carotenoid, tocopherol, and fatty acids or urinary nitrogen level (Okuda et al., 2009, 2019), and showed weak to moderate correlations in Japanese children and adolescents. The authors concluded that for younger children, the results should be interpreted with caution (Okuda et al., 2009).

One study (Raspini et al., 2021) modified the Willett FFQ, a validated semi-quantitative FFQ against 1-week diet records (Willett et al., 1985), to evaluate the Mediterranean diet adherence in children. The FFQ included 50 items asking food consumption during the past year. The percent agreement rates between diet record and the original Willett FFQ ranged from 48 to 77%, and the evaluation of reproducibility showed that intraclass correlation coefficients between two time points ranged 0.4–0.8, indicating moderate to excellent reliability values (Willett et al., 1985).

Other validated FFQs found in this review were tailored for specific geographic populations or nutrients. The FFQs for Spanish and Chinese children and adolescents had weak/moderate to high correlations with dietary recalls (Canals-Sans et al., 2022; Yeung et al., 2021; Zhu et al., 2020). A FFQ tailored for omega-3 consumption had moderate correlations with dietary recalls and an excellent test–retest coefficient (Ferguson et al., 2019). All were completed by parents of the participants with ASD.

Table 2 Summary of food frequency questionnaires and checklist used in populations with ASD

Measure	Target population	Type of instrument	Psychometrics/validity	Constructs measured	Availability
Block FFQ	Children and adults	147 food items or a 60-item brief FFQ	Multiple studies indicated > 0.7 correlations with other dietary records (Block et al., 1986, 1990)	Nutrients, food groups	NutritionQuest: https://www.nutritionquest.com/assessment/
Youth Adolescent Food Frequency Questionnaire (YAQ)	Children and adolescents (9–18 years)	152-item FFQ	Moderate correlations (0.5) with dietary recalls. Test–retest reproducibility weak (0.3) to moderate (0.6) (Rockett et al., 1995, 1997)	Nutrients, food groups	https://regepi.bwh.harvard.edu/health/KIDS/files/02.%202012%20YOUTH%20ADOLESCENT%20FOOD%20FREQUENCY%20QUESTIONNAIRE.pdf
Brief self-administered Dietary History Questionnaire (BDHQ)-10y and -15y	Japanese (10y: 7–15 and 15y: 13–15 years)	54 (10y) and 67 (15y) food items	Significant weak (0.2) to moderate (0.6) correlations with serum and urinary biomarkers (Okuda et al., 2009, 2019)	Nutrients	Not readily available
Shizuoka FFQ	Adults	87-food item FFQ over the previous month	Validated in Japanese (Akabori et al., 2015)	Nutrients	Not readily available
Modified Willett FFQ	Children aged 8–9 years, parent proxy	50 items in 11 groups	ICC ranged 0.4–0.8 and 48–77% agreement between diet record and FFQ (Willett et al., 1985)	Nutrients, foods	The modified version is not readily available The Willett FFQ available: https://regepi.bwh.harvard.edu/health/nutrition.html
Omega-3 FFQ	Children and adolescents (6–18 years), parent proxy	152-item based on foods that contain omega-3 fatty acids	No mean difference and moderate correlations (0.4) with the 3-day food recalls. Excellent test–retest coefficient (0.8) (Ritter-Gooder et al., 2006)	Omega-3 fatty acids	Not readily available
FFQ for Spanish adolescents	Spanish adolescents and adults, parent proxy	45 items in 16 groups	Moderate (0.4) to high (0.8) correlations with dietary recalls (Trinidad Rodríguez et al., 2008)	Foods, food groups	http://www.nutricionhospitalaria.com/pdf/4035.pdf
FFQ for Spanish preschool children	Spanish children aged 3–6 years, parent proxy	41 items	Weak (0.3) to high (0.7) correlations with dietary records (Esteban-Figuerola et al., 2020)	Foods, food groups	https://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0212-16112020000100015
FFQ for adolescents in Suihua, China	Adolescents aged 12–18 years, parent proxy	8 food groups and 86 food items	Moderate-to-high correlations (0.4–0.7) with dietary recalls (Xia et al., 2011)	Nutrients, food groups	Not readily available

Table 2 (continued)

Measure	Target population	Type of instrument	Psychometrics/validity	Constructs measured	Availability
FFQ for Chinese preschoolers	Chinese preschoolers, parent proxy	262 items in 10 groups	Significant weak (0.3) to high (0.8) correlations with dietary recalls (Kwok et al., 2013)	Nutrients, food groups	Not readily available
Food frequency checklist (Cornish, 1998)	Ages: 4–10, parent proxy	A checklist supplementary to 3-day food recalls	N/A	Food groups, food variety	Not readily available
FFQ adapted from Mind, Exercise, Nutrition…Do It! (MEND) Questionnaire (Hinckson et al., 2013)	Ages: 8–20, parent proxy	14 items adapted from MEND questionnaire	Not validated	Nutrients, food groups	Hinckson et al., 2013 (supplementary document) Coding: https://www.ncbi.nlm.nih.gov/books/NBK373986/
A structured self-administered questionnaire (no specific name) (Kotha et al., 2018)	Children, parent proxy	6 questions on diet and 6 questions on dietary habits	N/A	Food groups, dietary habits	Not readily available
A structured questionnaire (no specific name) (Weir et al., 2021)	Aged 16–90 years	7 questions on eating habits	N/A (Weir et al., 2021)	Food groups, foods	Not readily available

Other Tools to Assess Usual Dietary Intakes or Dietary Patterns

Other dietary intake assessment methods included observation (Liu et al., 2016; Sharp et al., 2011), a daily fruit and vegetable intake checkbox completed by adolescents aged 12–15 years (An et al., 2019), 1-year retrospective food diary completed by parents (Al-Farsi et al., 2013b), a self-administered questionnaire (6 questions on diet and 6 questions on dietary habits) completed by parents (Kotha et al., 2018), and a self-administered questionnaire (7 questions on eating habits) completed by individuals aged 16–90 years (Weir et al., 2021). Observation was used to collect data on nutrients, food groups, and food variety in children aged 2–7 years and was used to supplement food records. The 1-year retrospective food diary was used with the brief Block FFQ to assess folate and B_{12} intake in 3- to 5-year-olds. Mothers of children reported the food items the child had consumed during the year prior to their study participation (Al-Farsi et al., 2013b). The checkbox self-report for adolescents' fruit and vegetable intake and the self-administered questionnaire to measure children's food group intake by parent report were not supplemented by any other method.

PA Assessments

Accelerometer

Of the 47 articles reviewed that evaluated PA in individuals with autism, 27 used accelerometry (Bandini et al., 2013; Boddy et al., 2015; Chu et al., 2020; Garcia et al., 2020; Garcia-Pastor et al., 2019; Heffernan et al., 2018; Ketcheson et al., 2017, 2018; Lobenius-Palmér et al., 2018; Memari et al., 2013, 2017; Ogino et al., 2018; Oreskovic et al., 2020; Pan, 2008a, 2008b; Pan & Frey, 2006; Pan et al., 2015, 2016; Sandt & Frey, 2005; Stanish et al., 2017; Tyler et al., 2014; Wachob & Lorenzi, 2015). Actigraph was the most common brand of accelerometer, used in 78% of the studies (Boddy et al., 2015; Chu et al., 2020; Garcia et al., 2020; Garcia-Pastor et al., 2019; Haegele et al., 2021; Heffernan et al., 2018; Ketcheson et al., 2017, 2018; Lobenius-Palmér et al., 2018; Memari et al., 2013, 2017; Oreskovic et al., 2020; Pan, 2008a, 2008b; Pan et al., 2015, 2016, 2021; Stanish et al., 2017; Sung et al., 2021; Tyler et al., 2014; Wachob & Lorenzi, 2015). In 16 of the studies using accelerometers, participants or their parents were asked to complete a log to track when they wore the accelerometer (Bandini et al., 2013; Chu et al., 2020; Ketcheson et al., 2017, 2018; Lobenius-Palmér et al., 2018; Memari et al., 2013, 2017; Nguyen et al., 2021; Pan, 2008b; Pan & Frey, 2006; Pan et al., 2015, 2016, 2021; Sandt & Frey, 2005; Stanish et al., 2017; Tyler et al., 2014). Fifty-nine percent (16/27) of studies required that participants wear the accelerometer for at least 7 days (Bandini

et al., 2013; Boddy et al., 2015; Dennison et al., 2021; Garcia et al., 2020; Haegele et al., 2021; Heffernan et al., 2018; Ketcheson & Pitchford, 2021; Ketcheson et al., 2018; Ogino et al., 2018; Oreskovic et al., 2020; Pan & Frey, 2006; Pan et al., 2016, 2021; Stanish et al., 2017; Tyler et al., 2014; Wachob & Lorenzi, 2015), while other wear times ranged 3–5 days (Chu et al., 2020; Garcia-Pastor et al., 2019; Lobenius-Palmér et al., 2018; Memari et al., 2013, 2017; Nguyen et al., 2021; Pan, 2008a, 2008b; Pan et al., 2015; Sandt & Frey, 2005) or 1 day (Sung et al., 2021). Six studies used accelerometry and a PA questionnaire or observation tool (Bandini et al., 2013; Boddy et al., 2015; Nguyen et al., 2021; Pan & Frey, 2006; Sandt & Frey, 2005; Stanish et al., 2017).

Observational Tools

Three studies described use of observation tools to determine participant PA levels (Becerra et al., 2021; Boddy et al., 2015; Sandt & Frey, 2005). In two studies, the observation tools were used in addition to accelerometry, while one used the observational measure only (Becerra et al., 2021). The System for Observing Children's Activity and Relationships during Play (SOCARP) was used to examine play activities and behaviors of children with autism during times of recess at school (Boddy et al., 2015). Using the SOCARP, participants were observed in 10-s increments followed by 10 s of recording their observations, which was repeated over 5 min. In studies with typically developing children, the SOCARP has been shown to have good interrater reliability and energy expenditure estimates from SOCARP observations correlate significantly with accelerometry (Ridgers et al., 2010).

A second observational tool discovered in the literature is the Behavior of Eating and Activity for Children's Health: Evaluation System (BEACHES). BEACHES has been used to examine factors at home and school that affect PA levels in typically developing children (McKenzie et al., 1991) and has high interrater reliability. It has been used to assess PA levels in children with physical disabilities (Sit et al., 2013).

The remaining observational measure described was the Observational System for Recording Physical Activity in Children (OSRAC), which was used in a study to determine the effect picture schedules had on MVPA levels in children with ASD (Becerra et al., 2021). The OSRAC uses codes from Level 1 to Level 5 to label observed activity. Descriptors are provided for each level; activities that are categorized into Level 4 or Level 5 are considered MVPA. The OSRAC was developed in 2006 and has been shown to have high interrater reliability (Brown et al., 2009). It has been used to assess activity levels in typically developing preschool aged children (Hustyi et al., 2012), but not in children with ASD. There is also a version for elementary school children that also have good interrater reliability (McIver et al., 2016). Concurrent validity of the OSRAC with both heart rate monitors and pedometers has been established (Larson et al., 2011).

Validated PA Questionnaire

There were 17 different self-report PA questionnaires used in the studies reviewed. Nine questionnaires have been tested for their validity and reliability and used in various studies to assess PA levels in different populations; the summary of these questionnaires is described in Table 3. All nine questionnaires showed excellent test–retest (r or ICC > 0.7) and internal consistence (Cronbach's alpha > 0.7) reliability scores. However, the results of convergent validity indicated fair to moderate validity scores against accelerometers ($r = 0.3$–0.5).

Eight studies used self-report for PA questionnaires or accelerometry logs (Borremans et al., 2010; Chu et al., 2020; Hamm & Yun, 2019; Hillier et al., 2020; Mangerud et al., 2014; Pan et al., 2016; Sahlander et al., 2008), while 4 studies used self-report with parent assistance (Lobenius-Palmér et al., 2018; Neumeyer et al., 2018; Pan & Frey, 2006; Otsuki & Ohashi, 2014). Four studies used more than one questionnaire (Borremans et al., 2010; Neumeyer et al., 2017a, b, 2018). Moreover, four studies did not provide clear details about who completed the questionnaire or accelerometry logs (Ketcheson et al., 2017; Neumeyer et al., 2013, 2017a, b).

Other Tools to Assess Usual PA Behaviors

Eight questionnaires were created by the authors of their respective studies (Bandini et al., 2013; Borremans et al., 2010; Mangerud et al., 2014; Neumeyer et al., 2013, 2017a, b, 2018; Sahlander et al., 2008; Stanish et al., 2017; Dahlgren et al., 2021; Weir et al., 2021) and have not been validated or used in other populations. Bandini et al. (2013) described a questionnaire developed by their research team that asked parents to indicate the types and frequencies of activities their child engaged in over the previous 12 months. Stanish et al. (2017) interviewed parents and adolescents together and asked what activities the adolescent performed outside of school time and how often they engaged in those activities. Sahlander et al. (2008) used a self-report questionnaire that asks the participant to estimate their activity frequency. A survey by Dahlgren et al. (2021) asked four questions, two about PA levels and two about the amount of screen time. Weir et al. asked about the frequency and duration of exercise per week in a self-report survey about lifestyle behaviors (Weir et al., 2021).

Three unvalidated surveys were used in the studies and limited information could be found. The Youth PA survey was used in four articles by the same author group (Neumeyer et al., 2013, 2017a, b, 2018) and categorizes the respondent's

Table 3 Summary of parent-report questionnaires for physical activity

Measure	Target population	Type of instrument	Psychometrics	Constructs measured	Availability
Godin Leisure-Time Exercise Questionnaire (Godin, 2011)	Any age	Self-report questionnaire	Moderate correlation with Caltrac accelerometer (r=.50) (Eisenmann et al., 2002); excellent test–retest reliability (r=.81) (Sallis et al., 1993)	7-day recall of frequencies of strenuous, moderate, and mild activities > 15 min during free time	https://www.ons.org/sites/default/files/Godin%20Leisure-Time%20Exercise%20Questionnaire_070815.pdf
Oxford Physical Activity Questionnaire	10–19 years	Self-report questionnaire	Excellent test–retest reliability in typical secondary school students (ICC .76–.91); weak convergent validity with Caltrac accelerometer (r=.32) (Lubans & Sylva, 2009)	7-day recall of moderate to vigorous physical activity	Not readily available
Physical Activity for Older Children Questionnaire	8–14 years	Self-report questionnaire	Good test–retest reliability (r=.75 and .82) (Crocker et al., 1997); good internal reliability (r=.82 & .84) (Thomas & Upton, 2014); weak to moderate correlation to Godin (r=.41) and Caltrac accelerometer (r=.39) (Kowalski et al., 1997); may have lower validity in African American and Hispanic children (Moore et al., 2007)	7-day recall of moderate to vigorous physical activity levels during the school year	Not readily available
International Physical Activity Questionnaire	18–65 years	Self-report questionnaire	Good test–retest reliability overall (r=.80); fair to moderate agreement between IPAQ and accelerometer (ρ=.30)	7-day recall of activity level in 6 domains (Occupational, Transport, Yard/Garden, Household, Leisure, and Sitting)	https://www.sralab.org/rehabilitation-measures/international-physical-activity-questionnaire-long-form
Habitual Physical Activity questionnaire	Adults	Self-report questionnaire	Moderate validity for identifying older adults as low or high active (Hertogh et al., 2008); test–retest reliability is good for main sections of the questionnaire (r=.65–.89) (Pols et al., 1995)	12-month recall of frequency of PA in the areas of work, sports, and leisure (Baecke et al., 1982)	https://www.sralab.org/rehabilitation-measures/baecke-physical-activity-questionnairemodified-baecke-physical-activity
WHO Health Behaviour in School Children (HBSC) survey	School-aged children	Survey for parents	Good reliability (ICC=.77); moderate correlation between item and accelerometer data from US adolescents (r=.40) (Prochaska et al., 2001); poor to moderate test–retest reliability in a study of PA question (K=.6) (Booth et al., 2001)	7-day recall of frequency and duration of activity per day	Available online through the HBSC website: http://www.hbsc.org/methods/index.html

Table 3 (continued)

Measure	Target population	Type of instrument	Psychometrics	Constructs measured	Availability
Finnish Leisure Time Physical Activity Questionnaire	3–18 years	Parent Questionnaire (for 3–6 yo) Self-report Questionnaire (for 9–18yo)	Fair to good reliability (Internal consistency coefficients .44–.76) (Telama et al., 1997); Higher reliability for older age groups; Fair validity-low to moderate correlation between questionnaire sum scores and a physical activity index (r = .33–.54) (Raitakari et al., 1994)	7-day recall of PA level	Not readily available
Child/Adolescent Activity Log	Mean age 12 years	Self-report survey	Good test–retest reliability (r = .95 for original (Garcia et al., 1997); r = .98 for Iranian version); Good content validity (Taymoori et al., 2009); Weak to moderate criterion validity (r = .31–.47) with Caltrac acceleromter (Garcia et al., 1997)	Daily recall over 3 or 7 days of type, duration, and intensity of PA	Not readily available
Weekly Activity Checklist	4th–5th grade	Self-report checklist	Good test-rest reliability (r = .74); Low correlation with Caltrac accelerometer (r = .34, .26) for 4th graders (Sallis et al., 1993); Moderate correlation with heart rate index (r = .57) and low correlation with accelerometer (r = .3) for 5th graders (Sallis et al., 1996)	7-day checkoff of activities performed in the previous week	Available online through Dr. Sallis website: https://drjimsallis.org/measure_pacisapac.html

activity with labels of Sedentary, Low Active, Active, and Very Active. The Youth PA was developed at the Cincinnati Children's Hospital Medical Center. The PA Research Questionnaire (PARQ) was used in a study to assess physical fitness in adolescents with and without Asperger syndrome (Borremans et al., 2010). It includes questions regarding participants' knowledge of and feelings toward PA as well as their perception of their own PA level. The questions on the PARQ were reviewed by a panel of two physical therapists and one occupational therapist who determined the questionnaire adequate to gain information about the participants' PA. However, no other validation of the questionnaire exists nor does subsequent research indicate the PARQ is used in research studies.

In a study examining PA in adolescents with psychiatric disorders as well as those in the general population, the authors reference using a CAP survey (Mangerud et al., 2014). The study took place at the Department of Child and Adolescent (CAP) at St. Olav's University Hospital in Norway, which indicates the CAP survey is one of their designs. The CAP survey is not well-described and it is unclear what questions are included in this survey. The authors allude to another work of theirs that used the CAP survey (Mangerud et al., 2013); however, the only questions described are about pain, not PA.

Discussion

This scoping review aimed to summarize existing dietary intake and PA assessment tools for individuals with ASD, as well as their availability and prior use. One hundred fourteen articles were identified that assessed dietary behaviors and/or PA in individuals with ASD. The most commonly used dietary assessment methods found in this review—3-day food records and FFQs—are also commonly used in populations without ASD. The FFQs used in the studies identified in this review were intended for general populations, and some were tailored to specific age groups, race/ethnicity, or nutrients of concern. The most common tool used to assess PA was accelerometry, which is widely accepted as a valid measure of PA in children with and without disabilities. Evidence of validity and reproducibility of dietary intake and PA measures has been reported in typically developing individuals, but there were no assessment tools that were validated specifically for individuals with ASD. However, none of the studies reported any particular issues with using the measurement tools or concerns on assessing dietary intake or PA in individuals with ASD.

The results of this review showed that a number of studies assessed dietary intake and patterns of a diverse sample of individuals with ASD. Adults with ASD were capable of completing many types of dietary intake assessment tools, while parents completed dietary intake assessment for their children under 18 years of age in most studies. Using parents as proxy reporters has been identified as the most accurate method for typically developing children at least up to age 11 years (Burrows et al., 2019). Only one study relied on self-report of dietary intake for children, and the study used simple checkboxes to measure fruit and vegetable intake (Cornish, 1998). Image-assisted dietary assessment has been used in typically developing children and adolescents (Schap et al., 2014), as well as adolescents with intellectual and developmental disabilities (IDD) (Ptomey et al., 2015), to improve estimates of energy and macronutrient intake. However, it is difficult to determine which specific age an adolescent with ASD is capable of completing a dietary intake assessment tool without assistance. Researchers may need to pilot-test or examine the feasibility of administering a dietary intake assessment tool with target age groups prior to the study. Because dietary recalls and food records place a high burden on study participants and require training for both research staff and participants, various FFQs were used in several studies. Even though a few validated FFQs were used and readily available, some studies did not clearly indicate the validity and reliability of the FFQs and the questionnaires could not be found. Four questionnaires were written in languages other than English, and it is unknown whether those questionnaires are readily available in different languages. Developing a new dietary intake assessment tool without evidence of validity and reliability is discouraged.

While it is known that PA is important for health promotion in the ASD population, this study found that there is a significant lack of easy to use, inexpensive, and readily available assessment tools specifically designed to measure PA in children with ASD. Although accelerometry is considered to be an accurate method of assessing PA, it is not always feasible due to its cost and practicality of continuous use in children (Phillips et al., 2021). The use of questionnaires to assess PA may address these concerns; however, many questionnaires reviewed for this study were not readily accessible, which meant specific content could not be reviewed and there is no means by which the questionnaire could be used on a regular basis to assess PA for future research. Additionally, none of the questionnaires have been validated to use with the ASD population, so it is unknown if these questionnaires can achieve PA measurement comparable to accelerometry. This creates a challenge for assessing PA accurately and for problem solving solutions to improve PA in this population (Srinivasan et al., 2014). This study highlights the need for PA assessment tools that are designed specifically for individuals with ASD and have practical use and application.

Six of the PA questionnaires reviewed have been shown to achieve PA measurement comparable to accelerometry in individuals who are typically developing; however, most findings suggest weak to moderate correlations (Craig et al., 2003; Garcia et al., 1997; Godin, 2011; Kowalski et al., 1997; Lubans & Sylva, 2009;

Prochaska et al., 2001). Future research should include validating these measures in the ASD population. It is also possible that existing questionnaires may need to be modified, or new questionnaires developed, in order to incorporate some of the unique features of movement in individuals with ASD such as repetitive behaviors, narrow interests, or limited attention. Further research is needed to identify accommodations such as visual supports or parent assistance that may help individuals with ASD provide self-report on questionnaires related to PA.

Finally, in all but 4 studies (An et al., 2019; Matheson et al., 2019; Soden et al., 2012; Weir et al., 2021), dietary intake and PA were evaluated independently. Recent data have shown that individuals with ASD have a greater risk for obesity and diet-related chronic diseases, compared to their neurotypical counterparts (Curtin et al., 2014; Dhaliwal et al., 2019; Kahathuduwa et al., 2019; McCoy & Morgan, 2020). Lifestyle behaviors including diet, PA, and sedentary behaviors have been identified as contributing factors of obesity among individuals with ASD (Dhaliwal et al., 2019), yet the findings of the current review indicate that previous studies rarely investigated diet and PA behaviors together. Future research should consider the value of exploring dietary intake and PA comprehensively.

This study was limited by its methodology, as it did not include gray literature and review articles. As this was not a systematic review, we did not examine the rigor of study design or quality of data presented in each study. Nevertheless, this study provided a comprehensive, descriptive overview of the literature on dietary and PA behavior measurement in individuals with ASD. Moreover, the review process followed a comprehensive approach with consultation among all authors and reliability checks at every stage of the review. Search strategy development was led by an expert research librarian (AMH), and five of the authors were actively involved in article screening and data extraction and synthesis.

Conclusions

Based on this scoping review, 3-day food records are most commonly used for dietary intake and accelerometry is most commonly used for PA. Our findings highlight the need for instruments that are developed for and/or validated in individuals with ASD. Studies on dietary intake and PA in ASD are mostly on children, and dietary assessments are often completed by parents. When individuals with ASD report their own food intake or PA behaviors, not by their parents, it is important to establish or report the evidence of validity and reliability of the assessment tools. If existing assessment tools are not valid or reliable in individuals with ASD, adaptations or novel tools will need to be developed.

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Declarations

Conflict of Interest The authors declare no competing interests.

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