Static postural control among school-aged youth with Down syndrome: A systematic review

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ABSTRACT

Background: Youth with Down syndrome are characterized by motor delays when compared to typically developing (TD) youth, which may be explained by a lower postural control or reduced postural tone.
Objective: In the present article, we summarize research comparing the static postural control, assessed by posturography, between youth with Down syndrome and TD youth.
Methods: A systematic literature search was performed in 10 databases and seven studies, published between 2001 and 2017, met our inclusion criteria.
Results: Based on the present reviewed findings, it is impossible to conclude that children with Down syndrome present significantly lower static postural control compared to TD children. In contrast, findings showed that adolescents with Down syndrome tended to present significantly lower static postural control compared to TD adolescents when visual and plantar cutaneous inputs were disturbed separately or simultaneously.
Conclusion: The present findings should be interpreted with caution given the limitations of the small number of reviewed studies. Therefore, the static postural control among youth with Down syndrome should be further investigated in future rigorous studies examining the contribution of a range of sensory information.

Keywords: Down syndrome; posturography; balance; vision; plantar cutaneous sensitiveness.

1. Introduction

Extensive research has focused on the motor development of youth with Down syndrome. However, previous attempts at synthesizing these results were done more than 25 years ago [1-3]. Overall, results from these prior reviews showed that youth with Down syndrome present motor delays and difficulties when compared to typically developing (TD) youth. These motor delays may be explained by specific characteristics of youth with Down syndrome [1], such as skeletal problems (i.e., atlantoaxial instability or subluxation, joint laxity or hypermobility), hypotonia, kinesthetic perception problems, and obesity. It has been further hypothesized that these motor delays might be explained by a dysfunctional postural control system, that is "*the reduced postural tone of each child, which has a negative effect on the adequacy of co-contractions and balance reactions and is related to a defective proprioceptive feedback on posture and movement and to an increased joint mobility*" (p. 12) [4].

The examination of static postural control performance and strategy is of interest to advance our understanding of the motor development of youth with Down syndrome. Static postural control refers to the ability to control one's "*body position in space for the dual purposes of stability and orientation*" (p. 52) [5]. It is a complex process that requires the coordination of several sensory, motor, and biomechanical inputs [5,6]. It is generally accepted that the mean velocity of the center of pressure displacements is an indicator of postural stability with a greater velocity indicating a decrease in postural stability [6]. The static postural control of youth with Down syndrome is quantitatively measured and analyzed using force platform (also named stabilometric platforms or posturography) [5,6]. To our knowledge, no systematic review of the studies examining the static postural control (assessed by posturography) of youth with Down syndrome when compared to TD youth has yet been realized. Yet, such a systematic review appears critical to better understand whether targeted interventions are warranted to optimize the outcomes of static postural control of youth with Down syndrome. The purpose of the present systematic review is thus to summarize the findings from studies comparing the static postural control, assessed by posturography, between youth with Down syndrome and TD youth. The findings of retained studies will be summarized as a function of the samples' age category (i.e., children, adolescents, or mixed children-adolescents) and the testing conditions (i.e., visual disturbance, plantar cutaneous sensitiveness, and combination of visual × plantar cutaneous sensitiveness disturbances).

2. Methods

2.1. Sources of information and search strategy

Studies were identified by a systematic electronic search conducted in 10 databases (PsycARTICLES including PsycINFO, Scopus, SPORTDiscus with Full-Text and the seven following via EBSCO: Academic Search Complete, CINAHL Plus with Full-Text, Education Source, ERIC, Medline with Full-Text, Psychology and Behavioral Sciences Collection, and SocINDEX) without imposing any year restriction. This electronic search was conducted using the following three groups of terms: (Gr. 1) "Down syndrome"; AND (Gr. 2) balance OR "postural control*" OR "postural sway" OR "postural stabili*" OR "postural instabilit*" OR "postural adaptation*" OR "postural performance*" OR "postural perturbation*" OR "postural strateg*" OR posture*; AND (Gr. 3) child* OR adolescen* OR student* OR youth*. These grouping combinations were researched in the title-abstract-keywords of the articles published by the journals indexed in the databases. Finally, the reference lists of the reviewed articles were inspected to find other potentially relevant studies. This search was last updated on 11 June 2017.

2.2. Criteria for inclusion of the studies in the review

Studies were included in the systematic review if they met the following four inclusion criteria. First, studies had to include school-aged (6 to 22 years old) youth with Down syndrome. Studies of participants under the age of 6 were not included because it has been shown that the development of balance strategies is not achieved before this age in children [7]. Studies comprising both adolescents and adults with Down syndrome were eligible if the sample's mean age was lower than 18, or if results on postural control were presented separately for participants younger than 22 years old. Studies of adult samples were excluded.

Second, studies were considered relevant if they examined static postural control measured by posturography (i.e., using a forceplate or platform), which is now recognized as the gold standard for the assessment of postural control [8-10]. During such measurement, the participants must stand barefoot on one or both legs. Consequently, studies were excluded if they measured: dynamic postural control, posture using a posture/balance scale, or posture while the participants were either seated or wearing orthoses or sneakers/shoes. When the same sample or part of the sample was used in different publications, only one study was included.

Third, only case control studies examining differences in static postural control between youth with Down syndrome and TD youth were considered eligible. Intervention studies were also considered as eligible if pre-test measures comparing youth with Down syndrome and TD youth were available. However, case studies and non-original studies (i.e., comments, reviews, theoretical papers) were excluded.

Fourth, only studies published in English in a peer-reviewed journal were retained. Studies written in other languages, unpublished or published in non-peer-reviewed journals were excluded.

2.3. Eligibility of the identified studies

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement (PRISMA) [11], studies were identified as eligible based on the examination of their title-abstract and full text. The first two authors separately screened the title-abstract of the studies found in the databases. They then independently assessed the full text of the studies selected in the previous step to determine eligibility. These ratings were then reviewed by both authors and discrepancies were resolved by discussion.

2.4. Information extracted from the reviewed studies

The first two authors separately extracted the following categories of information from each reviewed study: (a) country and World Health Organization region (see www.who.int/about/regions/en/); (b) recruitment setting (e.g., community, foundation for youth with Down syndrome, regular school); (c) sample's age category (children, adolescents, and children-adolescents); (d) characteristics of the Down syndrome sample (i.e., size, percentage of boys, age range, mean age, and intellectual disability level); (e) characteristics of the TD sample (i.e., size, percentage of boys, age range, and mean age); (f) characteristics of posturography measures (i.e., acquisition frequency, trial duration, number of trials per condition, testing conditions, leg stance, and postural parameters); and (g) results (i.e., for each postural parameters and according to the sample age category and the testing conditions). These ratings were then reviewed by both authors and discrepancies were resolved by discussion.

2.5. Quality assessment of the reviewed studies

The quality of the methodology used in the reviewed studies was assessed by the first two authors using an adapted version of the quality rating scale developed by Negahban, Mazaheri Kingma, and van Dieën [12]. As illustrated in Table 1, this 8-item quality rating scale serves to assess the internal validity, statistical validity, and external validity of studies. More specifically, the internal validity of the study was measured using three items focusing on the reliability of postural measures, the presentation of postural assessment, and on the correction for confounding effects on postural measures. Two items focusing on the statistical validity of the reviewed studies measured the appropriateness of statistical tests and sample size. Finally, three items focusing on the external validity of the study examined whether sufficient information was provided about the participants' characteristics, instrumentation, and analyses. These ratings were then reviewed by both authors and discrepancies were resolved by the last author.

3. Results

3.1. Study selection

As reported in Figure 1, the search strategy identified a total of 1,113 articles and this number fell to 422 when duplicates were removed. The analysis of titles-abstracts revealed that 387 articles did not meet the inclusion criteria, leading to their exclusion. The full text of the 35 remaining articles was then examined, leading to the further exclusion of 28 articles (for the references of the studies, see the online supplements) that did not meet the inclusion criterion (see Figure 1 for reasons). Finally, seven studies [13-19], published between 2001 and 2017, met the inclusion criteria. These studies are described in Tables 2 and 3.

3.2. Characteristics of the studies

3.2.1. Sample characteristics and design.

Approximately two thirds of the studies were conducted in Europe (5/7). The two other studies were conducted in North America and South-East Asia. A total of 218 school-aged youth with Down syndrome (mean sample size = 24.2, range = 4 to 58) and 142 TD youth (mean sample size = 15.8, range = 4 to 33) were involved in these studies. Nearly half (3/7) of the studies recruited their participants at school. A single study mentioned the level of intellectual disability of the participants (i.e., mild to moderate). Moreover, based on the age range and/or mean age, three studies [13 (sample a), 14, 15 (sample a)] included children (age range: 6 to 13), five studies [13 (sample b), 15 (sample b), 16-18] included adolescents (age range: 10 to 20), and one study [19] included both children and adolescents (age range: 8 to 19). Finally, 64% (range = 53% to 70%) of the participants with Down syndrome were boys.

3.2.2. Characteristics of posturography measures.

Only five studies specified the acquisition frequency (in Hz) used in the data collection, and of these, four used a frequency of 30 Hz and higher (Table 3). The number of trials ranged from one time to three times (M_{times}= 2.3, SD_{weeks} = 0.7) and lasted from 15 seconds to 40 seconds (M_{sec}= 29.4, SD_{sec} = 6.3). Static balance was measured using a double leg stance (DLS) in all studies (Table 3). This assessment was conducted while using disturbing visual inputs (eyes opened, eyes closed) in six studies and disturbing plantar cutaneous sensitiveness (hard floor, foam floor) in three studies (Table 3).

As noted in Table 3, estimates of balance were based on: (a) the root mean square (RMS) and mean amplitude (in mm or cm; measured in the anterior-posterior and medio-lateral axes, except for one study [18]; i.e., standard deviation and average value of the distance between the maximum and minimum displacement of the COP in each or any direction) of the center of pressure (COP) in five studies; (b) the RMS and mean velocity (in mm/sec, cm/sec or m/s; measured the anterior-posterior [AP] and medio-lateral [ML] axes; i.e., standard deviation and average value of the total distance covered by the COP during the trial duration) of the COP in five studies; (c) the path length (PATH-L; in mm; i.e., total distance covered by the COP during the trial) in two studies; and (d) the standard deviation (SD) of the displacement of the COP or the COP area (in m^2; i.e., total area covered by the COP) in two studies. Higher values in these postural parameters indicates a poorer static postural control.

3.2.3. Comparison between youth with Down syndrome and TD youth.

Visual disturbance (eyes opened vs. eyes closed). As noted in Table 4, five studies statistically compared the static postural control (in DLS) among youth with Down syndrome with that of TD youth in eyes opened (EO) and/or eyes closed (EC) conditions only [13-15,18,19].

Children samples. Three studies [13 (sample a),14,15 (sample a)] statistically examined differences in static postural control in EO and/or EC conditions among children. As illustrated in Table 4, two of these studies revealed that children with Down syndrome, when compared to TD children, tended to present significantly higher mean COP-amplitude values (M-L and A-P) in EO and EC conditions [15, sample a], and higher COP-SD values in EO (M-L) [14]. Inversely, PATH-L is reported significantly higher for TD children compared to children with Down syndrome in EO and EC conditions [15, sample a]. Nevertheless, one study [13 (sample a)] failed to find any significant group differences for COP-velocity values (mean, M-L, and A-P) and COP-area values in EO and EC conditions.

Adolescent samples. Three studies [13 (sample b),15 (sample b),18] examined differences in static postural control in EO and/or EC conditions among adolescents. As illustrated in Table 4, two showed that adolescents with Down syndrome, when compared to TD adolescents, tended to present significantly higher COP-velocity values in EO (A-P) and EC (mean, A-P and M-L) conditions [13 (sample b)], and mean COP-amplitude values [15 (sample b)] in EO (A-P) and EC (A-P) conditions. Nevertheless, one study [18] failed to find any significant group differences for mean COP-velocity and COP-amplitude in EO and EC conditions.

Children-adolescent sample. Only one study [19] examined differences in static postural control in EO and/or EC conditions in a sample of children and adolescents. Findings from this study (Table 4) showed that youth with Down syndrome, when compared to TD youth, tended to present significantly higher mean COP-velocity values in EC and EO conditions and mean COP-amplitude (M-L) values in EO condition.

Plantar cutaneous sensitiveness disturbance (hard floor vs. foam floor). Only one study compared the static postural control among adolescents with Down syndrome and TD adolescents in hard floor (HF) or foam floor (FF) conditions [18]. As presented in Table 4, results showed that adolescents with Down syndrome tended to present significantly higher mean COP-velocity value than TD adolescents in FF, whereas no statistically significant differences were found in HF.

Combination of visual and plantar cutaneous sensitiveness disturbances. Three studies compared the static postural control among youth with Down syndrome and TD youth while combining visual (EO, EC) and plantar cutaneous (HF, FF) disturbances [16-18].

Children samples. None of the studies based on samples of children examined the static postural control while combining visual and plantar cutaneous disturbances.

Adolescent samples. As illustrated in Table 4, two of the studies [16,17] revealed that adolescents with Down syndrome, when compared to TD adolescents, tended to present significantly higher: (a) mean and RMS COP-velocity [16,17] values across conditions; (b) PATH-L [16] values across conditions; and (c) COP-RMS amplitude (M-L and A-P) in EO/HF [16], EO/FF [16,17], EC/HF (A-P) [16], and EC/FF [16] conditions. However, one study [18] failed to find statistical significant differences in mean COP-velocity and COP-amplitude between groups across conditions.

Children-adolescent sample. The study based on a sample of children-adolescents did not examine the static postural control while combining visual and plantar cutaneous disturbances.

3.2.4. Quality assessment of the reviewed studies.

Internal Validity. As reported in Table 5, only four studies satisfied at least half of the internal validity criteria [16,18,19]. The most frequently satisfied criteria were reliability of postural measures (3/7 studies), clear presentation of postural assessment (7/7 studies), and correction for the confounding effects of age (5/7 studies), sex (4/7 studies), body height (4/7 studies), and body mass (3/7 studies). However, none of the studies corrected for the confounding effects of body mass index (BMI) and physical activity.

Statistical validity. All studies used appropriate statistical tests, but none has determined the appropriateness of their sample size using a statistical power test.

External validity. All studies except one [14] satisfied at least half of the external validity criteria. The most frequently satisfied criteria were adequate information regarding age (7/7 studies), sex (4/7studies), body height (6/7 studies), body mass (5/7 studies) and physical impairment (6/7 studies), and the adequate description of postural measurement equipment (7/7studies), acquisition frequency (5/7 studies) and postural parameters calculations (7/7 studies). Few (or none) studies met the criteria related to adequate information regarding BMI (2/7 studies), physical activity (0/7 studies), level of intellectual disability (1/7 studies), and the adequate description of filtering (2/7studies).

4. Discussion

The purpose of the present systematic review was to summarize the findings from studies comparing the static postural control performance, assessed by posturography, between samples of youth with Down syndrome and TD youth. This research synthesis is essential to identify the needs of youth with Down syndrome and thus inform practices and interventions to enhance their motor development.

4.1. Static postural control with visual disturbance.

The postural sway increases when the visual reference related to the spatial orientation is removed during the maintenance of a normal quiet stance. A sensorial reweighting occurs and somatosensory inputs involved in stabilizing and organizing the body parts are tuned up in order to compensate and maintain postural stability [20-23]. Seven of the reviewed studies have examined the static postural control among youth with Down syndrome and TD youth in varying visual input conditions. Three quarters of these studies tended to show that children [14,15 (sample a)], adolescents [13 (sample b),15 (sample b)] and children-adolescents [19] with Down syndrome tended to present with significantly lower static postural control for some postutographic parameters than TD youth of the same age when visual inputs were altered, as well as when they were not altered. More specifically, these findings indicate that the integration of the visual components in postural balance control may not be responsible for the poorer static postural stability of youth with Down syndrome. It seems that their plantar cutaneous system does not adequately compensate for the lack of visual inputs when compared to TD youth. Nevertheless, findings from the studies focusing on children samples should be considered as preliminary. Indeed, one of the two significant studies comprised a very limited sample size ($N = 4$). Additionally, the most reliable and valid postural parameter (COP-velocity) [6] was found non-significant in these studies. Finally, given the limited number of studies, findings from the children-adolescents sample should also be considered as preliminary and need to be further examined.

4.2.Static postural control with plantar cutaneous sensitiveness disturbance.

By producing a multidirectional balance perturbation, the use of a foam surface interferes with balance control [6,24]. The upright stance thereby changes the foot's biomechanics with the consequence of altering the distribution of plantar pressures and increasing the activation of the ankle muscles linked with the location of the foot's center of pressure [6,21,25,26]. Regarding the plantar cutaneous sensitiveness condition (hard floor vs. foam floor), only one study has investigated this single sensory condition for adolescents with Down syndrome compared with

TD adolescents [18]. Findings suggest that adolescents with Down syndrome are more affected by the altered plantar cutaneous sensitiveness condition than TD adolescents. This means that adolescents with Down syndrome have systematically less postural stability while standing upright on a foam floor, indicating that an alteration of the standing surface has a more pronounced effect on the regulation of their static postural control. This specific postural sway reflects difficulties of the central integrative mechanisms of postural control of adolescents with Down syndrome to organize the stabilization of the body when plantar cutaneous sensitiveness inputs are challenged.

4.3.Static postural control with combination of visual and plantar cutaneous disturbances.

The combination of disturbed sensory inputs (vision and plantar cutaneous) provides a way to assess their combined importance in the regulation of the postural balance in an upright stance. Only three of the reviewed studies have examined the importance of visual and plantar cutaneous sensitiveness inputs on the static postural control of adolescents with Down syndrome. Two of the studies [16,17], both characterized by large sample sizes, showed that adolescents with Down syndrome tended to present a significantly lower level of static postural control than TD adolescents when visual and plantar cutaneous sensitiveness inputs were simultaneously altered. More specifically, this finding suggests that their postural control stance differs compared to TD adolescents when a reweighting of visual and plantar cutaneous sensitiveness inputs is needed in any disturbed sensory condition. This could be explained by a different allocation of the attentional resources allowed to the ponderation of this sensory information to organize the postural stability in an upright stance. However, the relative contribution of visual versus plantar cutaneous systems to postural control remains unclear and not documented. Finally, none of the reviewed studies of children, or of children-adolescents, examined group differences in static postural control while combining visual and plantar cutaneous sensitiveness disturbances; their effects thus need to be examined in future research.

4.4. Recommendations for future research.

The present findings should be interpreted with caution given the limitations of the reviewed studies, as well as the small number of studies that met our inclusion criteria. Detailing the limitations of these studies provides clear advice for researchers seeking to improve knowledge in this area of research. First, in the present review, the comparison of results across studies has been complicated by the fact that few studies relied on the same postural parameters. Consequently, to facilitate comparison, it is important for future research to focus on the most reliable and valid postural parameters, such as the mean or RMS COP velocity, as suggested by relevant research literature [6,27,28]. Moreover, only a few of the reviewed studies reported the mean and standard deviation of the postural parameters, as well as the number of participants for which the measures were available. This information should be more systematically reported in future studies to facilitate the estimation of effect sizes and standardized mean differences between youth with Down syndrome and TD youth.

Second, only one of the reviewed studies provided information about the postural control of youth with Down syndrome when the plantar cutaneous system was altered (hard floor vs. foam floor). Therefore, very little information is currently available concerning the relative importance of plantar cutaneous system when this sensory input is altered and how the central nervous system regulating the postural balance of youth with Down syndrome is able to adjust when this fundamental sensory information is lacking. The maturation of the cortical and central processes involved in the perception of verticality and in postural stability takes place during childhood in TD youth. Indeed, this maturation occurs later for vertical perception implying a delayed maturation of sensory integration processes [29]. Moreover, static postural control improves with increasing age due to a better use of sensorial inputs and cerebellar integration during development, allowing individuals to achieve a more efficient static postural control [30]. Consequently, the postural stability does not reach the adult level until the age of 13-14 years [31]. Indeed, vision plays a predominant role in adolescents' control of orientation and body stabilization. Youth clearly use different postural strategies and they are not capable of reaching postural performance levels comparable to those observed in adults [32]. The explanation is that youth are not able to use the available plantar cutaneous information to improve their static postural control due to a maturational lag compared to adults. This suggests that the mechanisms underlying static postural control are still maturing during adolescence, which might constitute a transient period for pondering and using adequately the proprioceptive inputs in sensory integration of static postural control [33]. Currently, there is no information related to this specific process in youth with Down syndrome, except from the observation that altered plantar cutaneous sensitiveness conditions lead to a reduced postural stability in those individuals when compared to TD youth.

Third, body weight/BMI [34] directly affects one's static postural control and there is a strong relationship between body weight/BMI and postural instability. It is well documented that youth with Down syndrome are at a higher risk of presenting with excess body weight or a degree of obesity [35,36]. However, only three of the reviewed studies have taken body mass into account [16,18,19], and none have considered body mass index. Further studies are needed to confirm that individuals with Down syndrome effectively present poorer postural stability compared to TD peers when controlling for the confounding effects of body weight and BMI, or whether observed differences are simply an artefact of BMI differences known to exist across these two populations [35,36].

Fourth, none of the studies have controlled for the potential confounding effect of physical activity. Indeed, it is reported in the literature that individuals involved in regular physical activity tend to report a better postural control than sedentary individuals [37]. Therefore, the findings of the reviewed studies may have been biased by this factor.

Fifth, the findings of this review are compromised by the small number of studies included. Although small sample sizes remain a perennial challenge in research with individuals with disabilities, further studies with larger sample sizes are recommended to better estimate the postural control differences between youth with Down syndrome and TD youth.

5. CONCLUSION

Findings from the present systematic review reveal that it is actually impossible to conclude that children with Down syndrome present a significantly lower static postural control assessed by posturography compared to TD children. Additionally, findings showed that adolescents with Down syndrome tended to present significantly lower static postural control compared to TD adolescents when visual and plantar cutaneous inputs were disturbed separately or simultaneously. However, given the limitations of the reviewed studies, additional rigorous studies are needed to investigate static postural control among this population. Finally, the present systematic review confirms that the static postural control should be considered as an important parameter to include in surveys of youth with Down syndrome, and as an important outcome for future exercise interventions.

Conflict of interest statement

The authors declare no conflict of interest.

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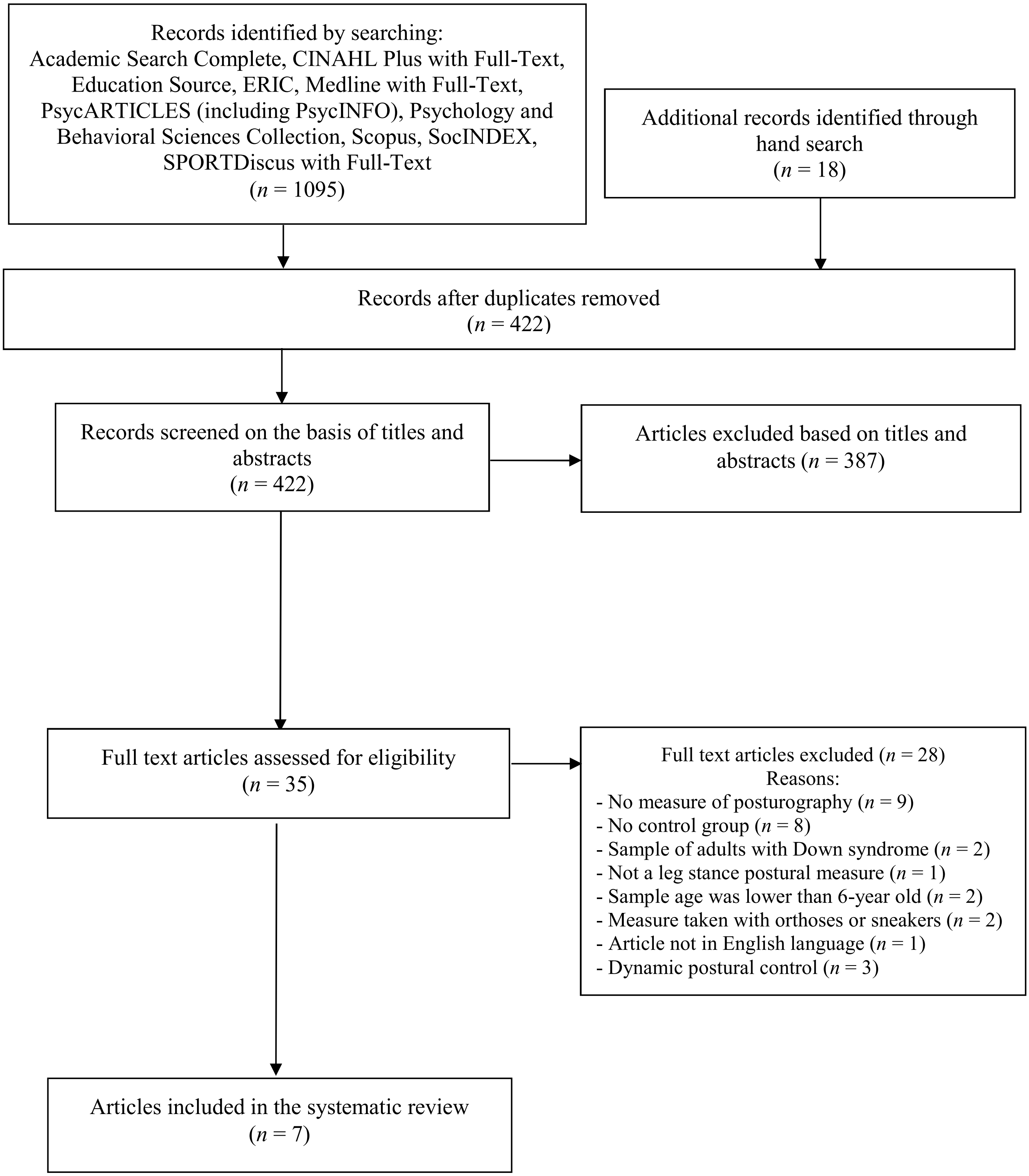

Figure 1- Results of the Search Based on the PRISMA Statement [11].

Table 1
Criteria used for the Quality Assessment of the Reviewed Studies.

Internal validity	Scoring
1. Reliability of postural measures	The criterion was satisfied if the sampling duration was mentioned and at least 3 repetitions were performed
2. Clear presentation of postural assessment	The criterion was satisfied if replication of the postural assessment is possible (e.g., instructions, environment, postural task) based on the information in the article
3. Correction for confounding effect on postural measures	The criterion was satisfied if confounders (i.e., age, sex, body height, body mass, body-mass index, and physical activity) were taken into account, or appropriate matching on postural measures was performed
Statistical validity	**Scoring**
4. The use of appropriate statistical tests	The criterion was satisfied if appropriate tests were used to assess differences in postural measures
5. Adequacy of the number of participants included in the study	The criterion was satisfied if the sample size was estimated by a statistical power test
External validity	**Scoring**
6. Sufficient information about the participants' characteristics	The criterion was satisfied if information about age, sex, body height, body mass, body-mass index, physical activity, physical impairment (e.g., sensorial, neurological, musculoskeletal), and level of intellectual disability was provided
7. Sufficient information about instrumentation	The criterion was satisfied if the postural measurement equipment was described clearly
8. Sufficient information about data analysis	The criterion was satisfied if information about the acquisition frequency, filtering, and postural parameters calculations was provided

Note. Adapted from [12].

Table 2. Main Characteristics of the Reviewed Studies.

Study	Country	Recruitment setting	Age Category	Sample with Down syndrome					TD sample			
				Sample size (*N*)	% of boys	Age range	Mean age	ID level	Sample size (*N*)	% of boys	Age range	Mean age
Sample a [13]	Spain	NM	CHILD	10	NM	6-11	8.7	NM	12	NM	6-11	8.3
Sample b [13]	Spain	NM	ADOS	11	NM	12-18	15.5	NM	12	NM	12-18	15.9
[14]	Canada	Foundation	CHILD	4	NM	6-13	10	NM	4	NM	6-13	9
Sample a [15]	Italy	Community	CHILD	37	NM	6-11	9.2	NM	10	NM	5-11	8.1
Sample b [15]	Italy	Community	ADOS	58	NM	12-19	16.7	NM	15	NM	13-20	18
[16]	Spain	Regular and special school	ADOS	32	53	10-19	NM	NM	33	58	10-19	NM
[17]	Spain	Regular and special school	ADOS	30	63	11-20	NM	NM	27	67	11-20	NM
[18]	France	Special school	ADOS	13	69	14-18	16.7	NM	11	73	12-18	15.8
[19]	Taiwan	NM	CHILD-ADOS	23	70	8-19	14.4	Mild-Mod	18	61	8-19	13.8

Note. ADOS = adolescents; CC = case control; CHILD = children; ID = intellectual disability; Mod = moderate; N = number; NM = not mentioned; TD = typically developing.

Table 3. Characteristics of Posturography Measures of the Reviewed Studies.

Study	Acquisition frequency (in Hz)	Trial		Testing conditions		Leg stance	Postural parameters
		Duration (in sec)	N per condition	VIS	PCS		
Sample a [13]	40	30	3	EO, EC	-	Double	COP-velocity (in m/s; mean, A-P and M-L) and COP-area (in m^2)
Sample b [13]	40	30	3	EO, EC	-	Double	COP-velocity (in m/s; mean, A-P and M-L) and COP-area (in m^2)
[14]	100 (filtered at 30)	30	3	EO	-	Double	COP-SD (M-L and A-P in cm)
Sample a [15]	NM	30	2	EO, EC	-	Double	COP-amplitude (M-L and A-P in mm), PATH-L (in mm)
Sample b [15]	NM	30	2	EO, EC	-	Double	COP-amplitude (M-L and A-P in mm), PATH-L (in mm)
[16]	30	30	2	EO, EC	HF, FF	Double	COP-RMS amplitude (M-L and A-P in mm), COP-RMS velocity (mean, in mm/sec), PATH-L (in mm)
[17]	30	30	2	EO, EC	HF, FF	Double	COP-RMS amplitude (M-L and A-P in mm), COP-velocity (mean in mm/s)
[18]	100 (filtered at 10)	40	3	EO■, EC■■	HF, FF	Double	COP-amplitude (in mm), COP-velocity (mean, in mm/sec)
[19]	NM	15	1	EO, EC	-	Double	COP-amplitude (M-L and A-P in cm), COP-velocity mean, in cm/sec)

Note. A-P = anterior-posterior; COP-amplitude = mean amplitude of the center of pressure; COP-area = total area covered by the centre of pressure; COP-RMS = root mean square of the centre of pressure; COP-SD = standard deviation of the position of the centre of pressure; COP-velocity = mean velocity of the centre of pressure; EC = eyes closed; EO = eyes opened; FF = foam floor; HF = hard floor; M-L = medio-lateral; N = number; NM = not mentioned; PATH-L = path length of the center of pressure; PCS = plantar cutaneous sensitiveness; ■named vision in the study; ■■named no vision in the study.

Table 4. Results of the Reviewed Studies.

Testing conditions	Age sample	Results	COP-velocity⁑			COP-area⁑	COP-SD⁑		COP-amplitude⁑		PATH-L⁑	COP-RMS amplitude⁑		COP-RMS velocity⁑
			Mean	A-P	M-L		A-P	M-L	A-P	M-L		A-P	M-L	
EO	CHILD	TD > DS									Sample a [15]			
		DS > TD						[14]	Sample a [15]	Sample a [15]				
		DS = TD	Sample a [13]	Sample a [13]	Sample a [13]	Sample a [13]	[14]							
	ADOS	DS > TD		Sample b [13]					Sample b [15]					
		DS = TD	Sample b [13],[18]		Sample b [13]	Sample b [13]			[18]*	Sample b [15]	Sample b [15]			
	CHILD-ADOS	DS > TD	[19]							[19]				
		DS = TD							[19]					
EC	CHILD	TD > DS									Sample a [15]			
		DS > TD							Sample a [15]	Sample a [15]				
		DS = TD	Sample a [13]	Sample a [13]	Sample a [13]	Sample a [13]								
	ADOS	DS > TD	Sample b [13]	Sample b [13]	Sample b [13]				Sample b [15]					
		DS = TD	[18]			Sample b [13]			[18]*	Sample b [15]	Sample b [15]			
	CHILD-ADOS	DS > TD	[19]											
		DS = TD							[19]	[19]				
HF	ADOS	DS > TD												
		DS = TD	[18]						[18]*					
FF	ADOS	DS > TD	[18]											
		DS = TD							[18]*					

Note. ADOS = adolescents; CHILD = children; A-P = anterior-posterior; M-L = medio-lateral; COP-amplitude = mean amplitude of the center of pressure; COP-area = total area covered by the centre of pressure; COP-RMS = root mean square of the centre of pressure; COP-SD = standard deviation of the position of the centre of pressure; COP-velocity = mean velocity of the centre of pressure; DS = Down syndrome; EC = eyes closed; EO = eyes opened; FF = foam floor; HF = hard floor; PATH-L = path length of the center of pressure; TD = typically developing; *COP-amplitude in any direction and not expressed belong A-P and M-L; ⁑higher values indicate a poorer postural control.

Table 4. (Continued)

Testing conditions	Age sample	Results	COP-velocity			COP-area	COP-SD		COP-amplitude		PATH-L	COP-RMS amplitude		COP-RMS velocity
			Mean	A-P	M-L		A-P	M-L	A-P	M-L		A-P	M-L	
EO/HF	ADOS	DS > TD	[17]								[16]	[16]	[16]	[16]
		DS = TD	[18]						[18]*			[17]	[17]	
EC/HF	ADOS	DS > TD	[17]								[16]	[16]		[16]
		DS = TD	[18]						[18]*			[17]	[16], [17]	
EO/FF	ADOS	DS > TD	[17]								[16]	[16], [17]	[16], [17]	[16]
		DS = TD	[18]						[18]*					
EC/FF	ADOS	DS > TD	[17]								[16]	[16]	[16]	[16]
		DS = TD	[18]						[18]*			[17]	[17]	

Table 5. Quality Assessment of the Reviewed Studies.

Studies	Internal validity								Statistical validity		External validity											
	1	2	3a	3b	3c	3d	3e	3f	4	5	6a	6b	6c	6d	6e	6f	6g	6h	7	8a	8b	8c
[13]	●	●	○	○	○	○	○	○	●	○	●	○	●	●	○	○	●	○	●	●	○	●
[14]	●	●	○	○	○	○	○	○	●	○	●	○	○	○	○	○	○	○	●	●	●	●
[15]	○	●	●	○	●	○	○	○	●	○	●	○	●	○	○	○	●	○	●	○	○	●
[16]	○	●	●	●	●	●	○	○	●	○	●	●	●	●	●	○	●	○	●	●	○	●
[17]	○	●	●	●	○	○	○	○	●	○	●	●	●	●	●	○	●	○	●	●	○	●
[18]	●	●	●	●	●	●	○	○	●	○	●	●	●	●	○	○	●	○	●	●	●	●
[19]	○	●	●	●	●	●	○	○	●	○	●	●	●	●	○	○	●	●	●	○	○	●
Total	3/7	7/7	5/7	4/7	4/7	3/7	0/7	0/7	7/7	0/7	7/7	4/7	6/7	5/7	2/7	0/7	6/7	1/7	7/7	5/7	2/7	7/7

Note. 1 = reliability of postural measures; 2 = clear presentation of postural assessment; 3a = correction for confounding effect of age; 3b = correction for confounding effect of sex; 3c = correction for confounding effect of body height; 3d = correction for confounding effect of body mass; 3e = correction for confounding effect of body mass index; 3f = correction for confounding effect of physical activity; 4 = appropriate statistical tests; 5 = adequate sample size; 6a = adequate information regarding age; 6b = adequate information regarding sex; 6c = adequate information regarding body height; 6d = adequate information body mass; 6e = adequate information regarding body mass index; 6f = adequate information regarding physical activity; 6g = adequate information regarding physical impairment; 6h = adequate information regarding level of intellectual disability; 7 = adequate description of postural measurement equipment; 8a = adequate description of acquisition's frequency; 8b = adequate description of filtering; 8c = adequate description of postural parameters calculations; ● = criteria satisfied; ○ = non-satisfied criteria.