THE EFFECTS OF PHYSICAL ACTIVITY ON BALANCE AND POSTURAL CONTROL IN PEOPLE WITH DOWN SYNDROME

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Review paper

Abstract
People with Down Syndrome (DS) often have impaired balance and postural control and result as less active than their peers, that can lead to reduced quality of life and movement skills. Effects of physical activity may be important in preventing falling risk and health consequences in people with DS. In this context, we conducted a literature search of original articles, published between January 2010 and January 2020, on the effects of physical activity on balance and postural control in people with DS. We found 16 articles from almost all continents, investigating the effects of different types of physical activity on static and dynamic balance and postural control. The included studies reported improvements in both static and dynamic balance with exercise programmes lasting at least 6 weeks and containing strength, aerobic and sensorimotor training. However, the most suitable type of physical activity for people with DS is not clear. In conclusion, physical activity is highly recommendable in people with DS, to improve their balance and prevent falling risk.

Key words: *Down Syndrome; physical activity; balance; postural control; postural stability.*

Introduction

Down Syndrome (DS) is a disease related to the presence of three copies of chromosome 21 and has a prevalence that varies from 1 on 400 to 1 on 1500 people in different countries [Kazemi et al, 2016]. This neurodevelopmental disorder affects mental and physical health [Bittles et al, 2007]. In particular, people with DS often have impaired balance [Villarroya et al, 2012] and result to be less active than their peers [Shields et al, 2018].

Both balance impairments and physical inactivity can lead to reduced quality of life and fundamental movement skills [Palomba et al, 2020; Capio et al, 2018]. Physical activity (PA) is defined by World Health Organization (WHO) as "any bodily movement produced by skeletal muscles that requires energy expenditure" and is recommended for promoting health in general population [WHO, 2010] and in people with disability, such as DS. A previous systematic review [Maïano et al, 2019] analysed the effect of targeted exercise for balance on static and dynamic balance in children and adolescents with DS. Li et al. [Li et al, 2013] found a positive impact of physical exercise on fitness in people with DS, with improvements on muscle strength and balance, showing promising results.

Sugimoto and colleagues [Sugimoto et al, 2016] found that neuromuscular training in people with DS had large to moderate effects on general strength, moderate to small effects on maximal strength, and small effect on functional mobility. In this context, starting from a systematic literature review focusing on the original articles published in the last ten years, the present study aims to investigate: (i) the main effects of PA on balance, posture and postural control; (ii) the comparison between results from different type of exercises.

Methods

We searched two online databases: PubMed (PM) and Web of Science (WoS). The selection of articles was made through ("Down Syndrome") AND ("Exercise"[Mesh]) AND (("Balance") OR ("Postural stability") OR ("Postural control")) for PM database and through ("Down Syndrome") AND (("Physical Activity") OR ("Physical Exercise")) AND (("Balance") OR ("Postural stability") OR ("Postural control")) for WOS. Moreover, we checked the reference list of all the screened long papers.

Papers Selection Criteria
The analysis of databases was made through the following criteria: (i) articles published between January 2010 and January 2020, in order to overview the most recent literature evidence; (ii) original articles, excluding reviews, commentaries, posters and proceeding papers; (iii) only full paper English written articles. After the first screening, two authors reviewed independently the founded articles with their title and abstract, in order to check the matching with the research aim. They selected papers aiming at investigating the effect of PA on balance, posture and postural stability, and combined the articles, excluding duplicates. Then, they checked the long paper of every of these articles excluding: (i) articles dealing with people with DS and other severe comorbidity (potentially influencing results); (ii) articles assessing the effects of PA on other outcomes.

Data extraction
From the selected papers the following data were extracted: (i) year of publication; (ii) participant characteristics (number, nationality, age, sex); (iii)

assessed outcome(s); (iv) control; (v) type of PA; (vi) duration and frequency; (vii) results.

Results and discussion

The review process is shown in the flow diagram in Figure 1, using the PRISMA guidelines [11].

After applying the paper selection criteria mentioned before, we checked 31 long papers and excluded: 3 articles dealing with people with DS and other severe comorbidity (influencing results); 12 articles assessing the effects of PA on other outcomes. Finally, the selected articles were 16. Table 1 shows their main characteristics.

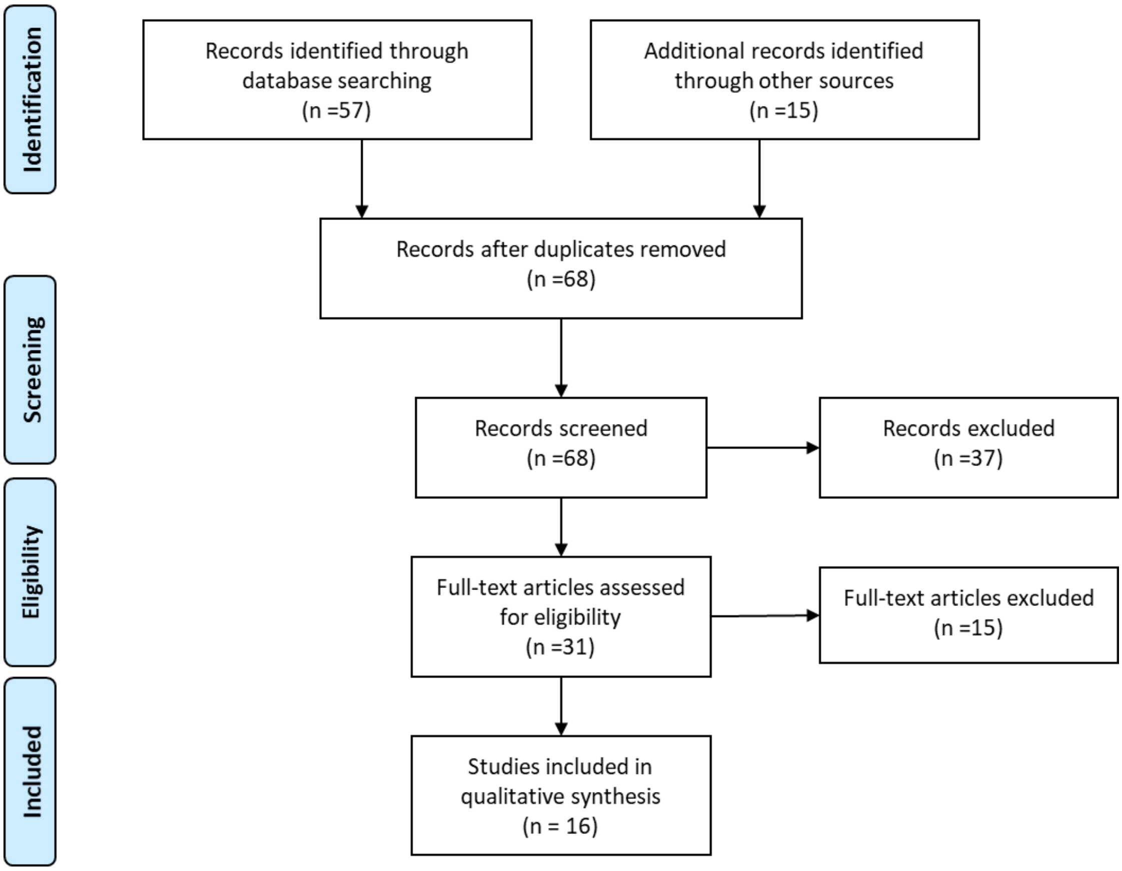

Figure 1. Flow diagram representing the literature review process.

Table 1. Selected articles main characteristics (n.a.: not available).

Author and year	Nation of participants	Total Participants Number (number of M: males)	Age range [years]	Participants in Experimental Group (EG)/Control Group (CG)
Rahman et al., 2010a	Egypt	26 (11 M)	2-5	13/13
Rahman et al, 2010b	Egypt	30 (13 M)	10-13	15/15
Gupta et al., 2011	India	23 (14 M)	7-15	12/11
Jankowicz-Szymanska et al., 2011	Poland	40 (20 M)	16-18	20/20
Ulrich et al., 2011	United States of America	46 (20 M)	8-15	19/27
Villarroya et al., 2013	Spain	57 (37 M)	11-20	30/27 (non DS)
Ghaeeni et al., 2015 [18]	Iran	16 (10 M)	8-13	8/8
Satiansukpong et al., 2015	Thailand	16 (n.a.)	7-13	8/8
Eid, 2015	Egypt	30 (17 M)	8-10	15/15
Boer & Moss, 2016	South Africa	42 (25 M)	18-50	26/16
Aly et al., 2016	Egypt	30 (21 M)	6-10	15/15
Amini et al., 2016	Iran	16 (16 M)	8-10	8/8
Eid et al., 2017 [24]	Egypt	31 (17 M)	9-12	15/16
Silva et al., 2017	Portugal	27 (n.a.)	18-60	14/13
Gómez Álvarez et al., 2018	Chile	16 (13M)	6-12	9/7
Alsakhawi et al., 2019	Egypt	45 (n.a.)	4-6	30/15

As we can see from Table 1, available studies cover all the continents, apart from Australia. Most of the studies were randomized control trial with DS people in the control group, apart from [Villarroya et al, 201] that used typically developed peers as control. The number of participants for each study ranged from 16 to 57 (with a mean value of 30.7), with a 58% of prevalence of male sex.

Almost all the included studies focused on children and adolescents with DS, only two studies [Boer et al, 2016; Silva et al, 2017] focused on adults. We have to note that one of the first experimental works dealing with the positive effect of PA on balance in DS people was performed on elderly [Carmeli et al, 2002]. Table 2 shows the main detailed information of the selected studies.

Table 2. Detailed information of the selected studies, with outcomes, type and duration of PA and main results, only statistically significant results are reported (CE: closed eyes, CFS: compliant-foot-support, CG: control group, COP: centre of pressure, COG: centre of gravity, EG: experimental group, FFS: fixed-foot-support, OE: open eyes, PA: physical activity, (+): statistically significant improvement, (=): non statistically significant improvement).

Author and year	Outcomes (method)	Type of PA	Duration	Main results
Rahman et al., 2010a	Balance (Bruininks-Oseretsky Test of Motor Proficiency)	Weight bearing exercise	6 weeks	EG: (+) static, dynamic and total balance scores
Rahman et al, 2010b	Balance (Bruininks-Oseretsky Test of Motor Proficiency)	Virtual reality-based therapy (Wii fit games)	6 weeks	EG: (+) mean balance score
Gupta et al., 2011	Balance (Bruininks-Oseretsky Test of Motor Proficiency)	Progressive resistive exercises for lower limbs and balance training	6 weeks	EG: (+) balance: one leg stance, one leg stance on a balance beam, walking forward on a balance beam, walking heel toe, walking heel toe on a balance beam, total score (=): one leg stance on a balance beam eye closed, walking forward on a line, stepping stick on a balance beam
Jankowicz-Szymanska et al., 2011	Static balance (one-legged standing on a balance platform with OE and CE)	Sensorimotor training programme	3 months	EG: (+) OE ad CE length of the path of the general COG and the time frame in which the vertical projection of COG remained within the 13 mm radius circle
Ulrich et al., 2011	Static balance (one-legged standing)	2-wheel bicycle	5 days	EG: (+) balance
Villarroya et al., 2013	Static balance (C1: OE/FFS; C2: CE/FFS; C3: OE/CFS; C4: CE/CFS)	Whole body vibration	20 weeks	EG: (+) mediolateral COP excursion and COP mean velocity in C4
Ghaeeni et al., 2015	Static balance (Modified Stork Stand Test)	Core Stability Training	8 weeks	EG: (+) static balance
Satiansukpong et al., 2015	Balance (Bruininks–Oseretsky Test of Motor Proficiency 2), postural control record form and visual motor integration (Beery VMI)	Thai Elephant-Assisted Therapy Programme	2 months	EG: (+) visual motor integration (=) balance and postural control
Eid, 2015	Dynamic balance (multiaxial balance system)	Whole body vibration	6 months	EG: (+) anteroposterior, mediolateral, and overall stability indices
Boer & Moss, 2016	Agility and dynamic balance (8-ft up-and-go test)	Continuous aerobic training (CAT) vs. interval training (IT)	12 weeks	EG: CAT: (+) agility and dynamic balance
Aly et al., 2016	Dynamic balance (multiaxial balance system)	Core Stability Training	8 weeks	EG: (+): anteroposterior, mediolateral, and overall stability indices
Amini et al., 2016	Dynamic balance (multiaxial balance system)	Backward walking training	8 weeks	EG: (+) anteroposterior, mediolateral, and overall stability indices (even at 10-week follow-up)
Eid et al., 2017	Dynamic balance (multiaxial balance system)	Isokinetic training	12 weeks	EG: (+): anteroposterior, mediolateral, and overall stability indices
Silva et al., 2017	Balance (Flamingo Balance Test) and postural control	Virtual reality-based therapy (Wii fit games)	2 months	EG: (=) balance
Gómez Álvarez et al., 2018	Postural control (OE and CE)	Virtual reality-based therapy (Wii fit games)	5 weeks	EG: (+) CE area of movement of the COP
Alsakhawi et al., 2019	Functional balance (Berg balance scale) and dynamic balance (multiaxial balance system)	Core stability training or treadmill walking	8 weeks	EG: (+) functional balance and overall stability

Table 2 underlines that, to assess balance, four studies used Bruininks-Oseretsky Test of Motor Proficiency [Rahman et al, 2010; 2010a; Gupta et al, 2011; Satiansukpong et al, 2016], a validated test in the DS population containing a specific section for balance. Another frequently used test for balance was one-legged standing test, such as Flamingo Balance Test and modified stork stand test, with [Jankowicz-Szymanska et al, 2012] or without [Ulrich et al, 2011; Ghaeeni et al, 2015; Silva et al, 2017] the use of a static balance platforms. Static balance systems were used even in measuring postural stability in different conditions [Villarroya et al, 2013; Álvareza et al, 2018], such as with open or closed eyes or changing the foot support. They allow to achieve quantitative measurement of centre of pressure position during time, and the changes due to modifying ocular or proprioceptive afferences.

Dynamic balance was assessed using a multiaxial balance system [Eid et al, 2015; Aly et al, 2018; Amini et al, 2016; Eid et al, 2017; Alsakhawi et al, 2019], allowing anteroposterior and mediolateral tilting, or 8-ft up-and-go test [Boer et al, 2016], requiring quick change of position, as in many activities of daily living. Postural control was assessed in [Satiansukpong et al, 2016; Silva et al, 2017], with [Satiansukpong et al, 2016] even assessing visual motor integration. No study used pressure mats to quantify static and dynamic balance, as in the sitting position [Caporaso et al, 2018].

PA varied in the experimental studies, using aerobic, strength and sensorimotor training programmes. They includes from Virtual reality-based therapy [Rahman et al, 2010a; Silva et al, 2017; Álvareza et al, 2018] to 2-wheel bicycle [Ulrich et al, 2011], from whole body vibration (WBV) [Villarroya et al, 2013; Eid et al, 2015] to weight bearing exercise (WBE) [Rahman et al, 2010], from progressive lower limb resistive exercises and balance training [Gupta et al, 2011] to the comparison among continuous aerobic training (CAT) and interval training (IT) [Boer et al, 2016], from Core Stability Training [Ghaeeni et al, 2015; Aly et al, 2018; Alsakhawi et al, 2019] to Thai Elephant-Assisted Therapy Programme [Satiansukpong et al, 2016], from backward walking training [Amini et al, 2016] or treadmill training to Isokinetic training [Eid et al, 2017]. The duration of the training programme varied from 5 weeks to 6 months, apart from [Rahman et al, 2010a] that used a 5-day training period with a follow-up at 12 months. Moreover, Boer and colleagues even published a follow-up study [Boer et al, 2018], after three months of detraining following [Boer et al, 2016].

They found significant reductions in functional tests, underlying the negative effects of detraining and suggesting the importance of continuative training programmes. The best way for testing balance in people with DS is not easily achievable, but we are confident that quantitative methods, such as multiaxial balance systems allowing the assessment of both static and dynamic balance in upright position or pressure mats for the assessment of sitting balance and trunk control, might represent adequate solutions. In the complex, PA improves both static and dynamic balance, even if it is difficult to discriminate the best combination of training programmes for DS people. No significant result is available about postural control. From the results mentioned in Table 2, we may conclude that a specific training for improving balance in DS people might last at least 6 weeks and include strength exercises, sensorimotor training, aerobic training or a combination of these mentioned exercises. Future studies may focus on the comparison of different types and quantity of PA, in order to achieve detailed information about it. Finally, quantitative measures, such as inertial sensors, could be even used to achieve information about PA quality and characteristics. Indeed, specific indices are often used to monitor PA in general population [Caporaso et al, 2020; 2020a]. This could lead to an improved objective evaluation of PA in DS people and to a regular monitoring to personalize the training programmes.

Conclusion

The available results show that regular PA may have a strong positive impact on static and dynamic balance in people with DS. From the results of the present review we tried to provide provisional recommendations about type and quantity of PA for an effective training programme for balance and possible reliable methods to assess it. However, the best training programme for this population is not clear, so future studies may focus on the comparison or combination of different types of PA to assess which one could maximize benefits. Apart from that, we are confident that a regular exercise should be proposed to every person with DS to allow balance and postural control improvements, to avoid the risk of falling and its negative impact on health.

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