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Determinants of hand function in children and adolescent with Down Syndrome-A scoping review

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ABSTRACT

Background: Down Syndrome (DS) is a genetic condition. Physical characteristics like short stature, hypotonia, small, and thick hands result in decreased grip and pinch strength and quality of fine motor tasks.

Purpose: The purpose of this review is to summarize the evidence of upper extremity physical characteristics and its influence on hand function in DS population.

Study Design: A scoping review.

Methodology: A comprehensive electronic literature search was conducted through PubMed, CINAHL, Cochrane Library. The search was limited to articles written in English and published between 2010 to 2021. Additionally, books were referred for a better understanding of the hand function in DS. The Preferred Reporting Items for Systematic Review and Meta-Analysis extension for scoping reviews (PRISMA-ScR) was adopted to develop the protocol.

Results: Following a detailed review of 28 articles meeting the inclusion criteria, fetuses with a diagnosis of DS are reported to have shortening of humerus on sonographic markers wherein 9% of fetuses had below 5th percentile shortening. Additionally, literature reports that during reaching there was increased trunk rotation (effect size = 0.88). DS population had 60% less grip strength, 33% less palmar pinch strength ,20% less key pinch strength and poor manual dexterity (CI = 4.5-5.5).

Conclusion: Findings of this review concludes that physical characteristics of the upper extremity have an influence on hand function performance in children and adolescents with DS.However, only arm length and hand span have been quantified and correlated with grip strength. Further work must focus on correlation of upper extremity anthropometry and overall hand function in children and adolscents with DS.

Introduction

Down Syndrome (DS), was first described by Dr John Langdon Down in 1866 as a genetic mental disability.[1] However, DS is an autosomal chromosomal genetic disorder that occurs due to overexpression of a gene on human chromosome 21.[2]

Individuals with DS exhibit deficiencies within multiple domains like physical and motor function. Body composition and muscle strength are vital parameters for children's gross motor, fine motor (such as tying a shoelace, printing or stringing beads),[31] and functional performance.[1] Physical characteristic exhibited by DS is short stature, small and broad hands with Simian crease, clinodactyly, low tone.[3] Motor performance in DS is addressed to be poor with weaker grip strength such that it affects functional domain and performance associated with daily activities.[4]

The children with DS often show 2 years of delays in their functional development, specifically in eye-hand coordination, bimanual tasks, gross and fine motor tasks. Features of ligamentous laxity, absence of some carpal bones, smaller hands, deflected fifth

Abbreviations: DS, Down Syndrome; TD, Typically Developing; ID, Intellectual disability; M-ABC, Movement assessment battery for children; CoP, Centre of pressure; RTG, Reach to grasp; BOT2, Bruininks- Oseretsky Test of Motor Proficicency -2; GMFM, Gross motor function measure; NMT, Neuromuscular tapping; T21, Trisomy 21.

Conflict of interest: We declare that there is no conflicting interest, guiding this research.

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finger are important predictors of multidomain deficiencies in individuals with DS.[5]

While summoning back to embryological development, DS individuals have delayed appearance of the primary center of ossification of digit 5, in comparison with premature fusion and thus explaining brachymesophalangia of digit 5 (wider and shorter middle phalanx of digit 5). Radiological studies infer the presence of pseudo-epiphysis of a base of the second metacarpal.[6,7]

Upper extremity function is usually associated with motor coordination, manual dexterity, muscle strength, and sensibility. Manual dexterity provides precision, speed and coordination of upper extremity movements to a task; grip and pinch strength provide quantitative measurement of upper extremity integrity.[8] Individuals with DS are restrained and sensitive from exploring different possibilities that require time to experience movement, to attain and refine fine motor skills.[9]

The quality of hand function often exhibits longer reaction time, high incidence of muscle coactivation, hypotonicity, ligamentous laxity. This alters the movement patterns in DS, inferred as "clumsy."[10] Proximal coordination of trunk and arm segment is a limiting factor for reach-to-grasp control in children with DS; also, slow and atypical movement contribute to late-onset of preparatory grip closure that limits manipulative skills and contributes to poor dexterity. Low muscle tone impairs recruitment and sequencing of muscle activation, resulting in compensation for instability and delayed interaction between the trunk and arm movements. Therefore, arm movements are poorly differentiated in DS, which prompts for atypical and immature grasps characteristics and orientation of hand to an object[11]

The International Classification of Functioning, Disability and Health in Children and Youth (ICF-CY) is referred to understand the pathway of a particular disease. Determinants of health play a vital role in assisting us in designing an assessment rehabilitation.[12] Amongst which, behavioral determinants of health consist of genetic conditions (such as DS, Klinefelter syndrome, etc.) as higher classification levels. This aids to connect us to different domains of ICF-CY.[13]

All these helps and guide us in understanding pathway of the physical, social and behavioral contribution of a population towards different aspects of ADLs and IADLs.

The various forms of studies performed to evaluate hand function in this population had insufficient results due to smaller sample size, incomplete tests and age appropriateness. Also, the systematic review published consisted of one component of hand function, whereas hand function is a broad term and has various sub-functions which needs to be roofed. The cross-sectional studies performed often had incomplete test results when compared with other populations (Typically developed [TD], other intellectual disabilities [ID]) and so results were inadequate and incomplete tests score were not involved in results. Physical characteristics studied are more restricted to hand span evaluation, which tells us about susceptibility towards hand injury and power grasp function.

Thus, in this scoping review, we aimed at exploring the comprehensive hand function of children and adolescents in DS. We also look for these altered comprehensive hand functions' effect on activities of daily living and instrumental activities of daily living.

Methodology

Searches

The methods of study analysis were ascertained. PRISMA-ScR guidelines were adopted for structuring this study. Data collection was done first by reading the title and abstract, second by preparing documents of selected studies obtained by applying search strategies in the database. It was discussed with reviewers and studies that had closed access, contact to correspondence author was established for same.

Data source information was obtained from studies listed in PICO format, studies including children and adolescents; focusing on hand function, grip strength, pinch strength, manual dexterity and fine motor function in the DS population.

Further data sources were obtained through textbooks, reference books, and cross-references on embryological development, musculoskeletal development, hand function and fine motor development in children with and without DS.

A total of 41,884 articles were listed on application of keywords to searching of the database, articles were selected on basis of inclusion criteria, out of which duplicate articles were removed

Screening

a) Human studies, b) studies presented in PICO format, c) studies exploring hand function in children and adolescents with DS with or without comparison with typically developed, d) age between 4 months to 25 years e) any study design (systematic reviews, RCTs, non-RCTs, cross-sectional, observational studies, pilot RCTs) f) Studies on hand function, upper limb function, reach, grasp, manipulation; manual dexterity, fine motor control, and coordination, precision grasping skills, g) studies in English language

Results

The survey comprised 41,884 scientific papers published nationally and internationally. Out of which 84 full-text articles were selected for review, among these 55 full-text articles were excluded. Out of the total, 6 articles were not accessible. Amongst all these, a total of 28 articles were included and studied in this review based on inclusion criteria.

a. Embryological studies: The studies relating to embryological abnormalities in DS was reflected in our search strategy as review articles and chapter from the textbook. Jonathan et al, in his review, stated shortening of humerus in sonographic markers in the first trimester (9% of fetuses had below 5th percentile shortening)[14]
b. Biomechanical constraints: Lopes et al, in their review stated that few studies performed the kinematic evaluation of upper limb in DS. They further added up stating that overall peak force and velocity in DS is lower and reaching tasks affects the dynamics of postural control. Also, this function was more feedback dependent.
c. Grip and pinch strength: Matute et al, examined the correlation of hand span on grip strength in DS and found that optimal grip span had a higher correlation in dominant ($r = 0.66$, $p > 0.05$) than nondominant hand ($r = 0.408$, $p < 0.05$). Jover et al, tested for grasping characteristics in DS and with TD; stated DS used fewer fingers to grip coin (effect size = 6), placing pegs (effect size = 0.5), picking up blocks (effect size = 0.92). Priosti et al, evaluated grip strength and manual dexterity in DS, and found no linear relation between dominant grip strength and manual dexterity ($r = 0.31$) and mean grip strength in DS were lower than TD ($p = 0.0$) and dominants' mean manual dexterity were lower in DS ($p = 0.00$). de Campos et al, (2010) study tested for reach and grasp in infants with DS, and found increase frequency of reach ($u(1) = 6.5$, $p = 0.01$) and decreased grasping frequency ($U(1) = 3.9$, $p = 0.04$). de Campos et al (2014), found DS infants used less unimanual grasping ($p = 0.03$) than bimanual grasping ($p = 0.009$) for smaller objects. Valvano et al, find-

ings during reach to grasp analysis in DS were increased in endpoint trunk rotation (effect size = 0.88), preparatory phase had poor anticipatory adjustment (effect size = 1.11 for gripping the aperture). Mullerpatan et al, findings stated that the DS population showed 60% less grip strength, 33% less palmar pinch strength and 20% less key pinch strength.de Campos et al (2014) studied the effect of object size on grasping in infants with DS and stated that DS infants touched larger objects with higher velocity ($p = 0.02$); in another study (2013) they found that DS infants reached frequently for large rough balls ($p = 0.004$) and large softballs ($p = 0.02$).

d. Manual dexterity and fine motor function: Vimercati et al, tested for fine motor function in DS through a drawing test, stating no significant difference was found in overall drawing performance but had increased velocity. Zareian et al, in their intervention study, stated improved reaction time in DS intervention post-intervention ($F = 75.5$, $p = 0.6$). dexterity improved ($F = 7.8$ for card sorting, $F = 23.0$ for arranging beads). Schott et al, in a cross-sectional study, stated the results of M-ABC, highest effect size found in "Forming letters using pen or pencil" ($r = 0.88$), "uses scissors to cut paper" ($r = 0.84$), "Fastens buttons" ($r = 0.78$). Marchal et al, in a longitudinal study, found manual dexterity is poor and testswere incomplete (CI = 4.5-5.5, SD = 5.0). Masumoto et al, found DS adolescents showed larger force generation and thus significant error in performing finger-tapping tasks.

e. Palmar arches and creases: There is lacunae in literature whilst addressing this sub-component of hand function, specifically concerning the DS population. However, their development and delayed are often expressed by a few authors but that was traced back four to five decades ago.

f. Dermatoglyphics: Lakshmi Prabha in her short review has given a highlight on dermatoglyphics in DS. Although a new term holds an important aspect when describing dental health in normal as well as DS population

Discussion

The results in Table 1 highlight the relationships and different aspects of hand function across life spans in children and adolescents with DS.

The acquisition of reaching and grasping represents an important milestone and contributing factor for functional independence during the growth period. Motor skills are distilled by repetitive and rhythmic task performance; also known as the repetitive perception-action-perception cycle, in children with DS this characteristic is refrain, and they have limitations while exploring their possibilities consequently requiring more time for acquiring and refining motor skills.[10]

In infancy reaching and grasping skills in the DS population are being influenced by various intrinsic factors, and there is a correlation between intrinsic (age, biomechanical factors, posture, etc.) and extrinsic (environment, object properties, and experience) factors. This results in the adoption of different strategies for reaching in infants with DS.[10] Intrinsic properties influence the accuracy and speed of reaching and grasping in infants with DS.[25] Pregrasping behaviors in infants with DS seemed to be less efficient in generating action-relevant information, and postgrasping behaviors required greater perceptual-motor demands and difficulty.[16] DS infant characteristics of grasping rely on object configuration rather than object properties. These infants require a longer time to adjust to uni and bimanual strategies which may be a functional limitation since early ages.[15]

Interest in an object often speaks about a child's engagement in an activity and development of language. In children with DS novel actions and objects might be repeated but a carry-over in their language and communication was reduced.[30] Reaching tasks in infants with DS leads to an exploration of environment and object, helping an infant with motor, and cognitive function.[34]

The birth performance-based measures and teachers' report reflects the bottom-up approach of current motor skills performance and long-term impression (top-down) in both DS and TD. Both the combined methods help in the evaluation of individually performed skills and thereby aid in tailored-made rehabilitation for each child.[11]

Children with DS demonstrated a moderate rate of grip and pinch strength reduction when compared to typically developed children. Also, weight, height, forearm length, hand length, and breadth were factors that influenced upper extremity strength differences.[26]

Hand strength and manual dexterity were similar in both genders; a correlation was also seen between age and hand function. Sound knowledge of manual skills is important for planning various aspects of developmental activities. Hand dynamometer is the gold standard tool for the evaluation of hand strength in healthy population and is used frequently. The same method can be used in DS population for evaluation of hand strength. It will help us to gain a sound knowledge about their hand strength.[22]

The three-dimensional analysis of kinematics for the evaluation of upper limb movements is necessary in children with DS to understand the velocity, speed and accuracy of movements. However, due to the dearth of standardizing protocol for evaluation of upper limb kinematics properties, there are often deviated protocols. Thus, a three-dimensional upper limb movement analysis should be developed for understanding the patterns of movements adopted during gripping and other hand function activities.[23]

Mental assessment at the age of 2 years, gender, and presence of infantile spasms can aid to some extent in predicting adaptive and motor skills by the end of school age in children with DS.[35] Understanding perceptual-motor development in children with T21, with an emphasis on atypical grasping features; and correlation of perceptual-motor functioning and grasping behaviors.[21]

The population with T21 often scores poorly in fine motor skills tasks because of specific brain and body characteristics. This lessens their effective dexterity skills and often contributes to their clumsiness and reduced participation in life situations represented in ICF (C-Y).[17]

The fine motor task in children with and without DS shows differences concerning developmental milestones, sensory, motor, cognitive and perceptual domain. These domains are often impaired in the DS population and many times inadequately addressed while testing fine motor tasks.[19] The adolescent with DS showed higher peak force-velocity and systematic delay on the onset of finger tapping movement. It may be due to differences in motor unit recruitment patterns.[18]

Significant limitations were found in RTG (reach-to-grasp) which contributes to more upper limb movement limitations and poor manual dexterity performance in school-aged children with DS.[29]

The postural sway (defined as small oscillatory motion made in body segments by an healthy individual to control and maintain an upright posture) in DS population is more with increased velocity in center of pressure (CoP). The CoP displacement was greater in medial/lateral directions. The motor skills performance such as standing, walking, running/jumping were inadequately achieved as per the results on gross motor functional measure (GMFM) and Bruininks-Oseretsky test of motor proficiency (BOT-2).[36]

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Table 1
Data charting and synthesis of results highlight the relationships and different aspects of hand function across life spans in children and adolescents with DS.

Sr no	Title	Study population age & gender	Level of evidence/ study design	Outcome measure	Method
1	Priosti et al,[24]	Down Syndrome 7-9 y/ both	II cross-sectional	Jamar dynamometer assessed grip strength using American Society of Hand Therapy guideline of measurement, Box and Blocks test assessed manual dexterity	Grip strength and manual dexterity were assessed for both hands. Each evaluation lasted for 15 min
2	Matute-Llorente et al, 2017[22]	Down Syndrome 15-18 y/ Both	II Cross-sectional	Hand span measured and Digital Dynamometer	Hand span was measured with hand widely opened, references from tip of thumb to the tip of the little finger; digital dynamometer was used for measuring grip strength with subject attaining standard bipedal position arm in abduction, elbow incomplete extension and forearm pronation. Subjects were recruited in two sections; one 27 subjects were tested and after a few weeks, 15 subjects were further recruited to determine optimal grip strength and reduce the risk of bias.
3	Zareian & Delavarian, 2014[5]	Down Syndrome 7-12 y/ both	II Experimental study	Bruininks-Oseretsky test to assess fine motor skills, Briggs-Nebes Handedness Inventory was used to establish laterality	Pre and post-test evaluations were performed. Hand laterality was established using Briggs-Nebes Handedness inventory. Subjects performed individual and group exercise of sport stacking in two sessions per week for 30 min. At first, edutainment video was set for patterning and speed, techniques were the point of emphasis
4	de Campos et al, 2010[10]	Down Syndrome and Typically developed 4-6 mo/ both	II Cross-sectional study	Alberta Infant Motor scale	Infants were placed on baby chairs reclined 50 degrees from horizontal. Pearl-like spherical markers were affixed to infants' wrists. An attractive spherical object was presented at infants' midline, shoulder height and arm's length for 1 min or until infant performed seven reaches. Reaching movements were recorded by using a three-camera (60 Hz) motion capture system 1 camera was positioned above and behind the chair and the other two were positioned in front of the diagonally to chair on right and left sides.
5	Lopes et al, 2018[23]	Down Syndrome and Typically developed	I Systematic review	PRISMA, PICO criteria, Crowe Critical Appraisal Tool (CCAT)for quantification of methodological quality of studies	The title and abstract were retrieved by researchers individually using a systematic strategy based on inclusion criteria. A total of 344 articles were retrieved and five full texts were included in this review.
6	Vimercati et al, 2015[19]	Down Syndrome and Typically developed 14-19 y/ both	II Clinical measurement	IQ assessment and SMART-D BTS (optoelectronic system) 200Hz frequency camera and integrated video system	The children were seated comfortably on an adjustable chair and in front of the desk. They were given a paper sheet with a printed figure (a circle, an equilateral cross, a square) and were asked to copy the illustrated figure with their dominant hand. Children were given modified ink pen with markers on the cap that allowed reconstruction of the trace drawn.
7	Camargo Oliveira & Cavalcante Neto, 2016[3]	Down Syndrome	I Systematic review	PRISMA	Exploratory and descriptive literature review, realized by digital media by recommendations of Cochrane Handbook for Systematic Reviews. Databases comprised LILACS, Medline, PubMed, Scielo, IBECS, Scopus. MeSH was selected for searching keywords, a medical classification system based on English language articles indexed in the area of research. Out of 38 articles, eight were selected on basis of common agreement amongst judges.

(*continued on next page*)

Table 1 (*continued*)

Sr no	Title	Study population age & gender	Level of evidence/ study design	Outcome measure	Method
8	Jover et al, 2010[21]	Down Syndrome and typically developed v 4-18 y/ both	II Cross-sectional	Movement Assessment Battery for Children (M-ABC)	Children were asked to write their name or their signature on a sheet of paper and to show which hand they preferred to brush their teeth or comb their hair; to determine preferred and non-preferred hand (PH) and (NPH) respectively. Then the children were asked to perform three manual tasks: a) posting coins, b) placing pegs, c) picking up blocks.
9	Memisevic & Macak, 2014[33]	One group (Down syndrome, Fragile X syndrome, Williams Syndrome, Prader Willi Syndrome) and a second group (unknown etiology of intellectual disability) 7-15 y/ both	II Comparative study	Purdue Pegboard test,	The test consists of four tasks to be performed by the children. The first three tasks required the children to place as many pegs in a peg-hole in a period of 30 s. The final task involves making as many assemblies as possible within one group
10	Chen et al, 2014[4]	Down syndrome Young male	II Interventional study	Hydraulic Dynamometer, treadmill, PAR-Q, Peabody picture vocabulary test	It is a pre-and post-evaluation study evaluating effectiveness of bout exercises on grip force in individuals with DS. The participants performed treadmill walking for 20 min following multistage protocol.
11	de Campos et al, 2011[25]	Down Syndrome and Typically developed 4-6 mo/ both	II Exploratory study	Apgar score, Cytogenic analysis	Infants were placed on baby chairs reclined 50 degrees from horizontal. Pearl-like spherical markers were affixed to infants' wrists. Four attractive spherical balls of different textures (two soft and two rigid) were presented at infants' midline, shoulder height and arm's length for 1 min or until infant performed seven reaches. Reaching movements were recorded by using a three-camera (60 Hz) motion capture system 1 camera was positioned above and behind the chair and the other two were positioned in front of the diagonally to chair on right and left sides. Kinematics characteristics of reaching were additionally performed by calculating deceleration time and maximum time by calculating maximum velocities value as a result of the difference of two minimum velocities.
12	de Campos et al, 2013[16]	Down Syndrome and Typically developed 4-6 mo/ both	II Observational study	Apgar score, Cytogenic analysis	Infants were placed on baby chairs reclined 50 degrees from horizontal. Pearl-like spherical markers were affixed to infants' wrists. Four attractive spherical balls of different textures (two soft and two rigid) were presented at infants' midline, shoulder height and arm's length for 1 min or until infant performed seven reaches. Reaching movements were recorded by using a three-camera (60 Hz) motion capture system 1 camera was positioned above and behind the chair and the other two were positioned in front of the diagonally to chair on right and left sides. Grasping behaviors were studied in four stages: pregrasping behavior, grasping, post grasping and post grasping exploration behaviors and frequencies of reaches were studied.

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Table 1 (*continued*)

Sr no	Title	Study population age & gender	Level of evidence/ study design	Outcome measure	Method
13	de Campos et al, 2014[15]	Down Syndrome and Typically developed 4-8 mo/ both	II Exploratory study	Apgar score,	Infants were placed on a reclined chair with truncal support. Four spherical objects (two large and soft and two soft and small) were placed in infant's midline at shoulder height in the line of arm. The object was presented for seven trials on both sides. Three cameras were used to record the reaching performance.
14	Fidler et al, 2014[30]	Down Syndrome and Typically developed Both	II Observational study	Leiter-Scale of performance, child development and family history, oral and written language scales, generativity performance	Different objects such as pipe cleaners, wooden beads, plastic coins, rubbery bracelets, paper cups for baking, straws, miniature pompoms, colored popsicles stick, foam sheets with holes punched around perimeter and lanyard strings. These objects created ambiguous plays. Participants' engagement was coded using Nodulus Observer XT coding software on following criteria: type of engagement and novel use of an object.
15	Holzapfel et al, 2015[27]	Intellectual disabilities 17-20 y/ both	II Interventional study	Modified Snellen chart, audiometer, Peabody Picture Vocabulary test 4th edition,	Participants completed cycling sessions using modified motorized stationary recumbent bicycling for 30 min three times per week for 8 weeks.
16	Jover et al, 2014[17]	Down Syndrome and Typically developed 5-20 y/ both	II Observational study	Movement Assessment Battery for Children (M-ABC)	The participants were recorded whilst they performed two tasks selected from M-ABC with both the hands preferred and non-preferred in sitting posture in front of a table
17	Latash et al, 2002[20]	Down Syndrome and age-matched typically developed 19-21 y/ both	II Cross-sectional Study	Experimental setup using sensor and piezoelectric effect tapping systems for recording a maximum voluntary contraction	All the participants performed trials of maximum voluntary contraction test using each finger separately and all four fingers together of the dominant hand. A ramp test was done with 12 trails with zero force for 5 sec projecting contraction and then a 30 percent increase in force for 2 s and repeat.
18	Lobo et al, 2015[34]	Down Syndrome, typically developed and high-risk infants 0-6 mo/ both	III Exploratory study	Observation of various grasping behaviours	Through various observations, the authors have described typical and atypical characteristics of the grasping behavior of infants. They have also highlighted stages of grasping and emphasized shifting of grasping behavior from general exploration to typical infant grasping and how it differs in infants with DS
19	Marchal et al, 2016[35]	Down Syndrome 6 months-10.7 y/ both	I Randomized Controlled Trial	Bayley Scale of Infant Development, Snijders-Oomen Nonverbal Intelligence test, Vineland Adaptive Behavior, M-ABC 2,	The participants were recruited right from their birth and a regular follow up every 2 mo were made. Their demographic data were recorded and different scales were used at different age intervals to score for various activities, such as early mental and motor development, intelligence at age of 10.7 y, adaptive functioning at age of 10.7 y, motor skills at age of 10.7 y.

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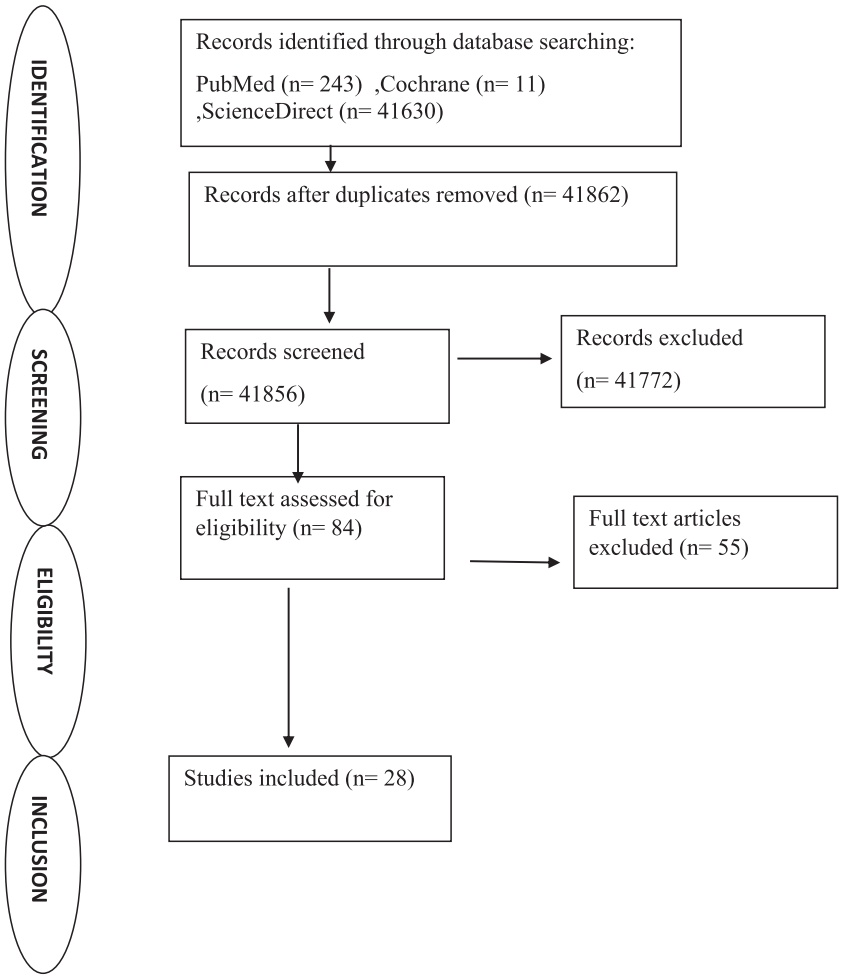
Table 1 (*continued*)

Sr no	Title	Study population age & gender	Level of evidence/ study design	Outcome measure	Method
20	Masumoto et al, 2012[18]	Down Syndrome 15-17 y/ male	II Cross-sectional	Edinburgh Handedness Inventory scale	The apparatus consisted of two load cells used for finger tapping were amplified with a strain amplifier and displayed on an oscilloscope. Participants were seated facing load cells and were instructed to perform uni and bi-manual tapping movements at a target force of 2N.
21	Rigoldi et al, 2015[28]	Down Syndrome 21-25 y/ both	IV Pilot experimental study	IQ	The NMT was applied over cervical spine bilaterally, over the shoulder and extensors of the hand and fingers of the same dominant hand. The optoelectric system was used for graphic picture tracing like squares, circles and triangles.
22	Schott et al, 2014[11]	Down Syndrome and Typically developed 7-11/ both	II Cross-sectional study	Test of gross motor development, M-ABC,	Data was collected from gym of schools where the children wore proper sports dresses and running shoes and had not been attending any motor activity prior
23	Valvano et al, 2017[29]	Down Syndrome and Typically developed 6-13 y/ both	II Exploratory study	Three-dimensional kinematic evaluation of RTG (reach-to-grasp)	Participants began the trial by sitting on a chair and no back support, arm on table. The object was placed at the end of reach point measuring full arm length. First was a kaleidoscope, that was kept and the participants had to reach and grasp it then bring it towards the eye for viewing. second was a small box to measure trunk and upper limb coordination.
24	Wang et al, 2012[36]	Down Syndrome and age-matched typically developed 14-17 y/ both	II Cross-sectional study	Force plate, GMFM, BOT-2	Participants were supposed to stand on force plates with eyes open and closed for measuring postural control for 15 s, then they had to concentrate on the visual signal that was the cue for throwing a ball, GMFM and BOT-2 4 subtests for further evaluation.
25	Herrero et al, 2017[37]	Down syndromev 3-5 mo/ both	II Exploratory study	Prechtl method of global and detailed general movement assessment	Within GenGM 5 min video recording of the infant's mobility was recorded during the period of wakefulness, feeding, supine lying.
26	John et al, 2016[26]	Down Syndrome and age-matched typically developed 9-16 y	II Cross-sectional study	Jamar hydraulic dynamometer, B&L gauge pinch dynamometer, anthropometric measurement of arm using semi-flexible tape	The students were recruited from two special schools and grip and pinch strength was measured using a standardized protocol for three trials and the best out three scores were taken as the final score.
27	Girish et al, 2013[32]	Down syndrome, Left-handedness, hypothyroidism	I Review	Fingerprints	I



PRISMA. flow diagram.

Children with DS present motor impairments pertinent for continued studies on this population, mainly based on appropriate motor interventions and construction of standardized scales for populations with DS. An opportunity for sports evaluation and intervention especially in the DS population will aid in enhancing the skills of hand-eye coordination and perceptual-motor activities. It will also allow the medical team for providing better guidance towards an evaluation of manual skills concerning reaction time. Focus on evaluation of fine motor skills and training them efficiently will help to improve quality of life in the DS population.[3,5]

A lower extremity rhythmical activity such as walking, stimulates peripheral sensory inputs, that reach the motor cortex, which in turn leads to improvement of grip strength in the DS population.[44] Finger coordination through repeated finger tapping tasks improves fine motor activities, and helps children to have a carryover effect in their ADLs and perform them with ease. The NMT (neuromuscular taping) aids by stimulating skin receptors and thus, creates sensory efference copy.[20] This intervention reduces dependency on external stimuli for functional tasks performance.[28]

Conclusion

Thus, from this review, we conclude that physical characteristics of upper limb (such as anthropometric measurements of arm, forearm and hand) have an influence on hand function performance (like grip and pinch strength, fine motor functions, manual dexterity) in the DS population. Further, a comprehensive evaluation of upper limb anthropometric measurements and hand function is required. A correlational study of the upper limb measurements and hand function will help us design tailored-made rehabilitation in DS population (PRISMA 1).

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References

1. Beqaj Samire, Tërshnjaku Esmira, Qorolli Merita, Zivkovic Vujica. Contribution of physical and motor characteristics to functional performance in children and adolescents with down syndrome: a preliminary study. *Med Sci Monit Basic Res.* 2018;24:159–167. doi:10.12659/MSMBR.910448.
2. Sandra G. Bellamy and Eunice Yu Chiu Shen. Genetic Feedback- A Paediatric Perspective. Sixth Edition. Mosby/Elesiver 3251 Riverport Lane St. Louis, Missouri 63043; 2017.
3. Oliveira Cristina, Cavalcante Neto Jorge. Manual dexterity of children and adolescents with down syndrome: systematic review of the literature. *J Genet Syndr & Gene Ther.* 2016;7. doi:10.4172/2157-7412.1000305.
4. Chen Chih-Chia, Ringenbach DRS, Snow M. Treadmill walking effects on grip strength in young men with down syndrome. *Res Dev Disabil.* 2013;35:288–293. doi:10.1016/j.ridd.2013.10.032.

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5. Zareian E, Delavarian F. Effect of sport stacking on fine motor proficiency of children with Down syndrome. *Int j sport stud*. 2014;4:1010–1016.
6. Cunningham C, Schester L, Black S, Liversidge H, Christie A. Developmental Juvenile Osteology. 2nd ed. Elesiver; 2016 London, UK.
7. James A, Merz Timothy, Janower Murray, Dorst John. Radiological features of the most common autosomal disorders: Trisomy 21–22 (Mongolism or Down syndrome), trisomy 18, trisomy 13–15, and the cri du chat syndrome. *Clin Radiol*. 1971;22:417–433. doi:10.1016/S0009-9260(71)80108-3.
8. Young Choi. *Comparison of grip and pinch strength in adults with dexterity limitations to normative values* Procedia Manuf; 2015:5326–5333.
9. Henderson, Pehoski. Hand Functions in the Child: Foundations for Remediation. 2nd edition. Elesiver; 2006 USA.
10. Campos Ana, Rocha Nelci, Savelsbergh Geert. Development of reaching and grasping skills in infants with Down syndrome. *Res Dev Disabil*. 2010;31:70–80. doi:10.1016/j.ridd.2009.07.015.
11. Schott Nadja, Holfelder Benjamin, Mousouli Ourania. Motor skill assessment in children with Down Syndrome: relationship between performance-based and teacher-report measures. *Res Dev Disabil*. 2014;35:3299–3312. doi:10.1016/j.ridd.2014.08.001.
12. ICF-An overview. PT6 Working paper (cdc.gov)
13. P ublic health classifications project – determinants of health; phase two: final report. classifications-project.pdf (nsw.gov.au)
14. LaCombe JM, Roper RJ. Skeletal dynamics of Down syndrome: a developing perspective. *Bone*. 2020;133:115215. doi:10.1016/j.bone.2019.115215.
15. Campos Ana, Cerra Larissa, Silva Fernanda, Rocha Nelci. Bimanual coordination in typical and atypical infants: movement initiation, object touching and grasping. *Res Dev Disabil*. 2014;35:2416–2422. doi:10.1016/j.ridd.2014.05.023.
16. Campos Ana, Costa Carolina, Savelsbergh Geert, Rocha Nelci. Infants with Down syndrome and their interactions with objects: development of exploratory actions after reaching onset. *Res Dev Disabil*. 2013;34:1906–1916. doi:10.1016/j.ridd.2013.03.001.
17. Jover Marianne, Ayoun Catherine, Berton Catherine, Carlier M. Development of motor planning for dexterity tasks in Trisomy 21. *Res Dev Disabil*. 2014;35:1562–1570. doi:10.1016/j.ridd.2014.03.042.
18. Masumoto Junya, Abe Takafumi, Inui Nobuyuki. Adolescents with down syndrome exhibit greater force and delay in onset of tapping movements. *Perceptual and motor skills*. 2012;114:826–836 10.2466%2F15.10.25.PMS.114.3.826-836.
19. Vimercati Sara, Galli Manuela, Stella G, Caiazzo G, Anci Andrea, Albertini Giorgio. Clumsiness in fine motor tasks: evidence from the quantitative drawing evaluation of children with Down Syndrome. *J Intellect Disabil Res*. 2014;59. doi:10.1111/jir.12132.
20. Latash Mark, Kang Ning, Patterson David. Finger coordination in persons with Down syndrome: atypical patterns of coordination and the effects of practice. *Exp brain res. Experimentelle Hirnforschung. Expérimentation cérébrale*.. 2002;146:345–355. doi:10.1007/s00221-002-1189-3.
21. Jover Marianne, Ayoun Catherine, Berton Catherine, Carlier M. Specific grasp characteristics of children with Trisomy 21. *Dev Psychobiol*. 2010;52:782–793. doi:10.1002/dev.20474.
22. Casajus José, Vicente-Rodríguez Germán, González-Agüero Alejandro, Matute-Llorente Ángel. Hand span influences optimal grip span in adolescents with Down syndrome. *Nutr Hosp*. 2017;34:626. doi:10.20960/nh.612.
23. Palma Lopes Jamile, Moura Renata, Lazzari Roberta, Duarte Natália, Dumont Arislander, Oliveira Claudia. Evaluation of upper limb movements in children with Down syndrome: a systematic review. *Infant Behav Dev*. 2018;51:45–51. doi:10.1016/j.infbeh.2018.03.001.
24. Priosti Paula, Blascovi-Assis Silvana, Cymrot Raquel, Vianna Denise, Caromano Fátima. Grip strength and manual dexterity in Down Syndrome children. *Fisioter. Pesqui*.. 2013;20:278–285. doi:10.1590/S1809-29502013000300013.
25. Campos, Ana, Francisco, Kelly, Savelsbergh, Geert & Rocha, Nelci. How do object size and rigidity affect reaching and grasping in infants with Down syndrome?*Res Dev Disabil*. 201; 32:246-52. doi: 10.1016/j.ridd.2010.09.023
26. Rebecca John, Dhanve Ankita, Rajani Mullerpatan. Grip and pinch strength in children with Down syndrome. *Hand Therapy*. 2016;21:85–89 10.1177%2F1758998316649102..
27. Holzapfel SD, Ringenbach SD, Mulvey GM, et al. Improvements in manual dexterity relate to improvements in cognitive planning after assisted cycling therapy (ACT) in adolescents with down syndrome. *Res Dev Disabils*. 2015;45-46:261–270. doi:10.1016/j.ridd.2015.08.003.
28. Rigoldi C, Galli M, Celletti C, Blow D, Camerota F, Albertini G. Does neuromuscular taping influence hand kinesiology? A pilot study on Down Syndrome. *La Clin Ter*. 2015;166(4):e257–e263. doi:10.7417/T.2015.1870.
29. Valvano Joanne, Hogy Sara, Worster Kate, et al. Analysis of reach-to-grasp by school-aged children with down syndrome elucidates limitations in upper extremity motor control. *Phys. Occup. Ther. Pediatr*.. 2017;37:1–15. doi:10.1080/01942638.2016.1261979.
30. Fidler Deborah, Will Elizabeth, Daunhauer Lisa, Tomaszewski Brianne, Visootsak Jeannie. Object-related generativity in children with Down syndrome. *Res Dev Disabil*. 2014;35:3379–3385. doi:10.1016/j.ridd.2014.07.024.
31. Maryanne Bruni. Fine motor skills for children with Down Syndrome: a guide for parents and professionals. 2nd edition. 2006
32. Jeevanandham, Lakshmi Prabha. (2021). A short review on Dermatoglyphics.
33. Memisevic Haris, Macak Amra. Fine motor skills in children with Down syndrome. *Spec. Edukac. Rehabil*.. 2014;13:365–377. doi:10.5937/specedreh13-7465.
34. Lobo Michele, Galloway James, Heathcock Jill. Characterization and intervention for upper extremity exploration & reaching behaviors in infancy. *J Hand Ther*. 2014;28. doi:10.1016/j.jht.2014.12.003.
35. Marchal Jan, Maurice-Stam Heleen, Houtzager Bregje, et al. Growing up with Down syndrome: development from 6 months to 10.7 years. *Res Dev Disabil*. 2016;59:437–450. doi:10.1016/j.ridd.2016.09.019.
36. Wang Hui-Yi, Long I-Man, Liu Mei-Fang. Relationships between task-oriented postural control and motor ability in children and adolescents with Down syndrome. *Res Dev Disabil*. 2012;33:1792–1798. doi:10.1016/j.ridd.2012.05.002.
37. Herrero D, Einspieler C, Panvequio Aizawa CY, et al. The motor repertoire in 3- to 5month old infants with Down syndrome. *Res Dev Disabil*. 2017;67:1–8. doi:10.1016/j.ridd.2017.05.006.

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