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Assessment of Toe Walking in Individuals with Autism Spectrum Disorder: The Toe Walking Scale (TWS)

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ABSTRACT

Autism spectrum disorder (ASD) is often associated with motor difficulties, among which walking plays a central role. Walking is a complex movement of the body that involves the limbs, trunk and pelvis in order to move forward safely and efficiently. Among the various atypical gait patterns in individuals with ASD is walking predominantly on tiptoes, i.e. on the front of the foot or on the toes themselves. This phenomenon, called "toe walking" (TW), describes the inability to place the heel on the ground while walking or at other times when standing (running, standing upright, etc.).

This behaviour is considered normal in the postural development of children up to 2-3 years of age, but many studies claim that it is more prevalent in individuals with autism spectrum disorder (ASD) than in their typically developing peers or peers with other disabilities.

Studies conducted to date describe TW mainly in qualitative terms, while very few studies have attempted to quantify it. The aim of this study is to provide a quantitative tool that supports both clinical and rehabilitation practice: the "Toe Walking Scale" (TWS).

Keywords

Autism spectrum disorder, Toe walking, Assessment, Motor difficulties, Gait disorders.

Introduction

Autism spectrum disorder (ASD) is often associated with motor difficulties, including delayed gross motor skill development (difficulties with balance, coordination, and large muscle movements, leading to difficulties with activities such as running, jumping, cycling, etc.) and fine motor skills (problems with precise movements and manipulating small objects, affecting skills such as drawing, writing, buttoning clothes, tying shoelaces, etc.), as well as difficulties with coordination (unstable gait, clumsy movement patterns, etc.), balance (impaired sensory perception and integration of vestibular stimuli, making movement and posture management complex) and body awareness (the position of the body and its movements in space) [1-5].

These motor differences stem from the way different areas of the brain are connected in brain connectivity, particularly between sensory and motor regions, which can affect the ability to synchronise movements (smoothly connecting movements to form a single action, such as arms and legs in swimming), coordinate actions (organising and controlling body movements to achieve effective and precise actions), facilitate social communication (difficulties in motor planning and execution can affect how people interact socially, compromising their ability to synchronise movements and facial expressions with others) and adaptive behaviours (manual dexterity, for example, is linked to adaptive behaviours, meaning that improving motor skills can lead to better daily functioning) [6-8].

In any case, among the most impaired motor functions in individuals with ASD, walking occupies a central position. It is the act of walking, a complex body movement involving the limbs, trunk and pelvis to move forward in space safely and efficiently.

It is an alternating and rhythmic process of locomotion, distinct from other forms such as swimming. The gait cycle is divided into two main phases: the stance phase (approximately 60% of the gait cycle, during which one or both feet are in contact with the ground) and the swing phase (when one foot is lifted off the ground and moves forward, while the other is in contact with the ground). When walking is impaired, this is referred to as gait disorders, which can indicate neurological or musculoskeletal problems and cause instability, physical pain, fatigue and even severe stress in individuals experiencing this condition, thereby compromising their quality of life [9].

Many individuals with ASD experience severe instability when walking, with fewer movements than their typically developing peers. In addition, to increase their walking stability, they tend to reduce their stride length, increase their stride width and base of support, and increase the time spent in the stance phase [10].

Biffi, Costantini, Ceccarelli, Cesareo, Marzocchi, Nobile, Molteni & Crippa [11], investigating motor differences between 15 children (average age 9 years) with ASD and 16 (average age 10 years) with typical development using GRAIL technology (*Gait Real-time Analysis Interactive Lab;* a platform that integrates a movement and gait analysis system on a treadmill and an immersive virtual reality system), found slight gait abnormalities in children with ASD: less force applied at the ankle and atypical flexion of the hip and pelvis during the step. Overall, these data highlight how these children exhibit an atypical gait pattern. Furthermore, it appears that reduced joint mobility is directly related to the severity of autistic symptoms.

Among the various atypical gait patterns in individuals with ASD is walking mainly on tiptoes, i.e. on the front of the foot or on the toes themselves. This phenomenon, called "toe walking" (TW), describes the inability to place the heel on the ground when walking [12,13].

Toe Walking

Toe walking is the habit of walking on the balls of the feet, without the heels touching the ground. It is a way of walking that allows them to move quickly, shift their weight forward and reduce the need to bend and lift their legs, thus expending less energy. In addition, walking on tiptoes makes the child more stable and allows them to maintain better balance; however, if the behaviour persists after the age of 2-3 and is accompanied by other signs of atypical development, it can become a useful indicator to consider when assessing the possibility of a neurodevelopmental disorder, including autism.

In fact, TW has been observed in children with speech delay or cognitive developmental delay, cerebral palsy, muscular dystrophy and in children with autism [14-17]. In the latter, approximately 30% walk on their toes, unlike individuals with other disabilities or typical development [16,18,19]. Why does TW have such a marked incidence in ASD? And what could be the causes?

Providing comprehensive answers to the above questions is very difficult, if not impossible; However, the first question can probably be attributed to the motor difficulties of these individuals, which include coordination problems, delays in motor development, incorrect posture, and stereotypical movements, manifesting themselves in a wide range of symptoms, such as difficulty walking or running, clumsiness in handling objects, and, indeed, walking on tiptoes.

As for the second question about possible causes, these may have several explanations related to the typical characteristics of autism and the person's functioning profile, including:

1. *Sensory hypersensitivity*: Walking with the whole foot touching the ground may be uncomfortable or even unpleasant due to hypersensitivity to touch or pressure. Walking on tiptoes reduces the surface area of the foot in contact with the ground, limiting exposure to sensory stimuli that the child may find uncomfortable. Therefore, walking on tiptoes is negatively reinforced (removal of discomfort and/or annoyance).

2. *Self-stimulatory behaviour (stimming)*: Toe walking can be a self-stimulatory behaviour that provides comfort or emotional self-regulation and allows for better management of stress or sensory overload. In addition, several studies [20-22] have shown a positive correlation between motor difficulties, including toe walking, and the presence of restricted and repetitive behaviours in individuals with autism; therefore, poor motor control may be associated with an increase in these behaviours (stereotypies, limited interests, resistance to change, rituals, etc.).

However, walking on tiptoes attracts the attention of others, who reinforce it positively (making it more difficult to extinguish), fuelling a spiral of stress in the child who, in an attempt to self-regulate their emotions or feel more secure in an environment they perceive as unpredictable or chaotic, resorts more to this atypical gait.

3. *Motor and coordination difficulties*: Walking on tiptoes may be a strategy adopted to manage problems with balance or movement, motor coordination and difficulties in performing complex movements or regulating posture, as it helps them feel more stable or in control. For example, the association between TW and the labyrinthine tonic reflex (a reflex aimed at maintaining the vertical position of the head in relation to the various positions of the trunk) supports the idea that underlying motor deficits contribute to the development of certain behaviours, such as toe walking [23].

In any case, walking on tiptoes alters the natural alignment of the body, causing overload on certain parts of the musculoskeletal system. This can lead to postural problems, with the risk of developing misalignments of the spine, hips and knees.

4. *Muscle stiffness or hypotonia*: Stiffness in the calf muscles or tension in the tendons, such as the Achilles tendon, makes it easier to walk on tiptoes (this can limit ankle flexibility and make it more difficult for the child to put their heels on the ground, even if they want to). Conversely, with low muscle tone (hypotonia), walking on tiptoes can become a way to compensate for the difficulty of

maintaining correct posture while walking.
However, walking constantly on tiptoes can lead to a shortening of the Achilles tendon.

5. ***Differences in sensory integration*****:** Toe walking can be a way to better manage balance and body awareness, which in normal walking requires the integration of various sensory information, including that from the vestibular system (responsible for balance), the proprioceptive system (which regulates the perception of the body in space) and the visual system (which allows us to orient ourselves in the environment and gather information about reality from it).

Toe walking, therefore, is often a combination of sensory reactions, self-regulating behaviours and motor difficulties, but the specific reasons for this behaviour can vary and may be related to how the child perceives and reacts to their environment.

What if it were superstitious learning? According to Skinner, superstitious behaviour develops through operant conditioning when an organism performs a random action that coincides with the moment when positive reinforcement occurs (e.g., the arrival of food, drink, a game, etc.)[1]. Even if the action did not cause the reinforcement, the organism repeats the behaviour in the hope that the association will be repeated, mistakenly believing that the action influenced the outcome. In accordance with Skinner [24], we could hypothesise that toe walking is a superstitious behaviour, linked to a particular consequence (positive reinforcement) received in the past (precisely while walking on tiptoes), which was pleasant for the subject. Superstitious behaviour is an irrational belief that associates certain actions (e.g., walking on tiptoes), objects or events with a causal power over future events, even though there is no logical link. These beliefs are often motivated by a desire to have a sense of control or security in the face of uncertainty, and can manifest themselves through various rituals (e.g., avoiding specific numbers or colours, etc.) or performing certain actions (such as walking on tiptoes).

How can we quantitatively assess the behaviour of a child who walks on tiptoes? In addition to performing a functional analysis, trying different combinations of various conditions (attention, escape, access to tangible objects and automaticity), it would be advisable to use an assessment tool that meets objective reliability criteria. The authors have developed the Toe Walking Scale (TWS) to meet this need, which will be presented in the next section.

[1] Skinner [24], in one of his experiments, dispensed food to pigeons in a cage at regular intervals, regardless of what they were doing. Initially, the pigeons did not pay attention to the mechanism that dispensed food, but over time they began to exhibit bizarre behaviours (such as spinning around or rocking their heads). Skinner noticed that the pigeons began to repeat those behaviours before obtaining food, almost as if that behaviour were the trigger for that reward. Other pigeons, placed in different cages, began to behave in the same way, persevering with the behaviour even though it did not lead to any result in most cases. Skinner concluded that a false correlation had been established between the action and the reinforcement, creating a superstitious behaviour based on chance.

The Evaluation of Toe Walking

As we have seen, walking on tiptoes is a behaviour that can be linked to ASD, although it is not exclusive to this disorder: toe walking can, in fact, be a strategy used by children to self-regulate, trying to reduce the intensity of sensory stimuli coming from the feet and body; but, in addition to being a serious social stigma, it profoundly affects balance, posture and personal autonomy. For all these reasons, it is important to objectively assess various behaviours that may characterise it (analysis of gait, sensory processing, posture, etc.), in addition to a thorough physical examination to rule out underlying causes such as neurological disorders (cerebral palsy or other neurological dysfunctions, spinal or spinal cord disorders, etc.), muscular (assessment of leg and calf muscle tone, tendon reflexes, muscle strength, etc.) or sensory (tactile hypo- or hypersensitivity, information processing, etc.). One tool that seems to partially meet these requirements is the Toe Walking Scale (TWS; Table 1) developed by the authors of this study. This scale is a tool that allows the severity of toe walking in children with ASD to be identified.

During the development of the tool, an item analysis was carried out on 102 subjects aged between 3.2 and 5.6 years (mean age = 3.10 years) to verify the clarity and adequacy of the items, listed in random order, and to obtain, in case of difficulty, indications for a linguistic and functional review of the items.

At the end of this process, the TWS was developed, consisting of 25 items to be administered to caregivers. The items were selected through four distinct phases:
Phase 1. Analysis of the scientific literature on toe walking.

Stage 2. Interpretation of the data collected and indication of the subjects to whom the questionnaire was administered in the pre-test stage, with a different number of items from the final selection (approximately 80 items).

Phase 3. Selection of the items that best met the criteria chosen for the construction of the instrument.

Phase 4. Experimental administration to a sample of subjects for psychometric evaluation.

The implementation of these phases reduced the margin of ambiguity of the items as much as possible, while facilitating a more accurate assessment of TW.

A 4-point numerical Likert scale (from 0 to 3) was chosen to code the responses on the Scale, where "0" corresponds to "not emitted" behaviour; "1" corresponds to "sporadically" emitted behaviour; "2" corresponds to "often" emitted behaviour; and "3" corresponds to "always" emitted behaviour.

The sum must be transcribed in the square with the highlighted sides of the TWS (Table 1) corresponding to the "SO" (score obtained). The score is then divided by 75 (MOS, maximum score obtainable) and multiplied by 100; the result is transcribed in the "SI" (Severity Index) column in Figure 1.

TOE WALKING SCALE (TWS)

Name: _____ Age: _____ Date: _____

Diagnosis: _____ Observer: _____

Instructions: Below are some items describing the behaviour of some children who walk on tiptoes. Read the descriptions carefully and choose the answer you agree with most, then mark the number in the right-hand column of the sheet with a cross: "0" corresponds to "No, never", "1" to "Yes, sometimes" (1 to 5 times every 5 minutes, or for 2 minutes in a row, even with short intervals of 1-3 seconds), "2" to "Yes, often" (6 to 12 times every 5 minutes, or for 3 minutes in a row, even with short intervals of 1-3 seconds) and "3" corresponds to "Yes, always" (more than 12 times every 5 minutes, or more than 4 minutes in a row, even with short intervals of 1-3 seconds).

There are no right or wrong answers. Before answering, carefully observe the child's behaviour as described in the item. If you are unsure about a score, always choose the lowest one.

01. Shows difficulty interpreting sensory information (heat, cold, bright lights, noises, smells, handling objects, etc.), reacting excessively or insufficiently to stimuli	0	1	2	3
02. Walks on tiptoes with or without shoes	0	1	2	3
03. Walks on tiptoes on soft surfaces (e.g., sand, carpet, etc.)	0	1	2	3
04. Adopts unusual postures (muscle stiffness, legs clamped together, shoulders raised, arms crossed, jaw clenched, fingers tense, rhythmic hand movements, etc.) in various contexts of life	0	1	2	3
05. When placing their heels on the ground, they spread their legs apart, rotating their feet outwards	0	1	2	3
06. In a supine position, pushes off with only the toes against the wall	0	1	2	3
07. If someone tells them to walk properly, they place the entire sole of the foot on the ground for less than 20 seconds	0	1	2	3
08. When standing on tiptoes, the distance between the heel and the ground is > 6 cm	0	1	2	3
09. He stands on his toes in a static position, without performing any activity, on a hard surface for more than one minute	0	1	2	3
10. He runs or jumps on his toes	0	1	2	3
11. When sitting or leaning his back against the wall, he rests only his toes on the floor	0	1	2	3
12. Walking on his toes occurs only at certain times (excitement, happiness, tiredness, etc.)	0	1	2	3
13. Shows generalised difficulty in motor planning (coordination of movements)	0	1	2	3
14. When moving, has difficulty keeping the head upright and in line with the torso (without leaning forward), looking straight ahead	0	1	2	3
15. Has difficulty walking on uneven surfaces or riding a bicycle	0	1	2	3
16. Walks on tiptoes on a hard surface (e.g., floor, road, etc.).	0	1	2	3
17. Climbs and descends stairs on tiptoes.	0	1	2	3
18. Remains standing on tiptoes even when engaged in an activity with an object placed on a table.	0	1	2	3
19. Stands on tiptoes in a static position, without performing any activity, on a soft surface for more than one minute	0	1	2	3
20. Has difficulty performing body movements effectively and accurately (throwing, grasping, balancing on one leg, fitting geometric shapes together, etc.)	0	1	2	3
21. Walking on tiptoes is associated with self-stimulatory behaviours (rocking, waving hands, clapping hands or feet, pacing back and forth, etc.).	0	1	2	3
22. Shows sensitivity to touch (discomfort or pain) and to stimuli that would not normally be painful (light touches, fabrics in contact with the skin, movement of air, etc.).	0	1	2	3
23. Walking on tiptoes occurs mainly in moments of stress or cognitive/sensory overload (too many stimuli at once: information, noises, lights, interactions).	0	1	2	3
24. Shows difficulty with balance and postural control.	0	1	2	3
25. Walks and/or stands on tiptoes in different contexts (home, school, etc.).	0	1	2	3

Table 1: La Toe Walking Scale (TWS).

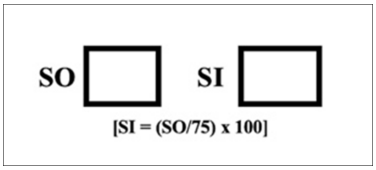

Figure 1: The arithmetic sum of the scores for each individual item must be entered in the box with the highlighted sides of the TWS. The same sum must then be entered in the "SO" (Score Obtained) box in Figure 1, then divided by 75 (Maximum Score Obtainable) and multiplied by 100; the result must be entered in the "SI" (Severity Index) box and is expressed with 4 "judgements": "Mild" if the score is between 0 and 20%, "Moderate" if it is between 21% and 50%, "Severe" if it is between 51% and 80%, and "Very severe" if it is > 80%.

The TW assessment is expressed in four 'ratings': 'VERY SEVERE' if the score is above 80%, 'SEVERE' if it is between 51 and 80, "MODERATE" if it is between 21 and 50, and 'MILD' if it is between 0 and 20. The 'VERY SEVERE' and 'SEVERE' ratings necessarily require further medical investigation (which should actually be carried out whenever the child walks on tiptoes for a prolonged period of time) because they could indicate neuromuscular disorders (such as cerebral palsy, Duchenne muscular dystrophy, etc.), orthopaedic disorders (such as a retracted Achilles tendon or other deformities), or sensory disorders (problems with the vestibular system), etc. The "MODERATE" assessment, on the other hand, excludes medical causes (neurological, orthopaedic, muscular, etc.) and draws attention to the idiopathic aspect of toe walking, which could be due to habit, familiarity or learning. The "MILD" rating considers toe walking to be a temporary habit, especially if the child can walk with their whole foot on the ground when asked to do so.

The reliability of the Scale, i.e. its ability not to be overly influenced by internal factors (ambiguity in the wording of the questions or variability of the phenomenon to be observed) or external factors (time of administration or characteristics of the examiner), was calculated using two methods: 1) agreement between independent observers and 2) internal consistency. To analyse the agreement between independent observers, the TW was administered, with the relevant instructions, to two different operators who were tasked with completing it by observing the same subject, but at different times and in different environments without consulting each other. Inter-observer reliability, measured using Cohen's k correlation coefficient, was 0.81 ($p<0.01$). In addition, the internal consistency of the Scale was also assessed using Cronbach's alpha, which showed a value of 0.83 ($p<0.01$). Both results are statistically significant and confirm the validity of the instrument (both in terms of the consistency of the questions and the objectivity of the observation). The test-retest analysis, carried out three months later, showed a value of 0.85 ($p<0.01$).

In addition to providing indications on possible treatment, the Scale also assesses the reduction in toe walking behaviour over time.

Treatment of toe walking

The treatment of toe walking depends on several factors: the child's age, the underlying cause, the severity of the problem, etc., and may include ABA-oriented treatments, physiotherapy, stretching, the use of braces, etc.; and, in more severe cases, even surgery to lengthen the Achilles tendon. Therefore, there is currently no single intervention that can satisfy all the factors mentioned above, and the treatments that are often implemented do not satisfy the same indication or have the same effectiveness, so it is important to know how to adapt the treatment to the specific situation. Furthermore, although this behaviour is present in several individuals with ASD, it is not a typical characteristic of the disorder, and treatment depends on the severity of toe walking (Table 1) and the child's functional profile. In any case, before starting any educational intervention, it is always advisable to carry out a clinical assessment.

Methodology

Participants

Giorgio, Mario and Matteo are three children aged 5.3, 3.9 and 3.2 years old, respectively, all diagnosed with ASD and undergoing ABA (Applied Behaviour Analysis) treatment for 60 hours per month (divided between home and school), the first since February 2024, the second and third since September 2024.

At the beginning of treatment, in addition to the administration of the VB-MAPP (Verbal Behaviour Milestone Assessment and Placement Program; [25]) for a functional assessment, which proved to be rather deficient in relation to their chronological age, direct observation was also carried out in different life contexts. In these contexts, the children showed restricted, repetitive and unusual interests that were not appropriate for their chronological age: mannerisms, stereotypical and repetitive behaviours, difficulty in relating to peers and in imitative play. In addition, they always moved around on tiptoes, attracting the attention of adults and peers, who thus reinforced their behaviour. In view of the above and analysing the children's behaviour at home and in the classroom and the functional analysis (which provided information on the consequences of the behaviour but not on its antecedents), it was decided to complete the assessment by administering the TWS to the three children (Tables 2, 3 and 4).

After further medical examination, given the severity of his toe walking, Giorgio underwent Achilles tendon lengthening, which was necessary because the tendon was so retracted that it prevented proper walking and ankle mobility, and conservative treatments had not been effective.

Mario, on the other hand, despite the severity of his toe walking and Achilles tendon retraction, underwent conservative treatment, using the unconventional "most-to-least prompting" procedure [26]: this strategy begins with more invasive assistance to ensure a correct response and gradually reduces the level of support as the subject becomes more independent. In other words, after a thorough medical examination (medical history, physical examination, foot flexibility, tendon length measurement, etc.), a baseline measurement of the height of the heel from the floor was taken, which was 6 cm. At this point, "special" shoes were

made with a heel composed of removable 0.5 cm layers of leather. Initially, the number of layers in the heel corresponded to the 6 cm (Most) baseline; therefore, the child had to rest the heel of the shoe on the ground, as he was unable to lift it any higher. After about three weeks, one layer was removed from the heel, resulting in a heel height of about 3 cm (Least), which satisfied the treatment outcome.

Currently, the child wears normal shoes, placing his heel completely on the ground even when barefoot. Matteo's medical examination failed to identify any pathological conditions (neurological, motor, sensory, etc.) related to the problem (idiopathic toe walking; [17,27]).

Therefore, through the medical history and the mother's account of the child's various developmental stages, an attempt was made to identify any contextual situations related to the problem; that is, the circumstances, constraints and specific elements that may have influenced the problem in each context. Understanding these situations was fundamental to resolving the problem effectively, because it involved not only analysing the problem itself, but also the environment in which it manifested itself and the contingencies that influenced the behaviour.

In fact, the mother reported that at around ten months of age, the child was placed in a baby walker to allow him to move around effortlessly in his own environment. Thus, whenever his mother called him, the child would quickly move on tiptoes with his body leaning forward in the direction of his mother, who would reinforce his behaviour with smiles, caresses and, often, even a biscuit. Without meaning to, the mother accidentally associated the behaviour of moving on tiptoes, with his body leaning forward, with a positive consequence (social and edible reinforcement), resulting in "superstitious" behaviour: that is, the child associated the random behaviour (moving on tiptoes) with the positive event (biscuit, caress, smile) that occurred shortly afterwards. After this association, Matteo learned that repeating that behaviour (walking on tiptoes) could influence future outcomes and result in rewards (social and/or edible): on the one hand, there is the person repeating the same act (toe walking) and, on the other, there is the expected event (rewards) which occurs a certain number of times, some of which will coincide with the superstitious gesture. From that moment on, even with the intermittent provision of reinforcement, the behaviour of walking on tiptoes became more reinforced. So how can we extinguish it?

To extinguish Matteo's superstitious behaviour, it was necessary to stop any reinforcement that kept it active. In practice, this meant ignoring the superstitious behaviour and avoiding providing any kind of reward (positive or negative reinforcement), even accidental, and acting on the environment to eliminate the reinforcements that maintained it. In addition, the child was heavily reinforced whenever he placed his heel on the ground. From an operational point of view, after a baseline to check the child's time spent on his toes (approximately 80% of the time the child was standing, whether walking, running or standing still, for example, near the table, he was on his toes), the following strategies were implemented (Figure 2):

- *Identification of reinforcement*: understanding what sustained the superstitious behaviour (edible and social reinforcements).
- *Removal of reinforcement*: avoiding providing the reward that maintained the behaviour by ignoring the toe walking behaviour. During this phase, the superstitious behaviour initially increased in intensity, as if it were a last desperate request for reinforcement, but it continued to be ignored until it gradually became extinct.
- *Modification of the environment*: modify the environment to remove the stimuli that triggered the superstitious behaviour (the intervention was implemented during the summer period from the closure of the school until its reopening to avoid the attention of classmates, which had been very reinforcing in the past; checking the consistency and coherence of the procedure also at home).
- *Reinforcement of alternative behaviour*: reinforce the most functional alternative behaviour (DRA) (placing the heel on the ground, even if only for a few seconds) [26].

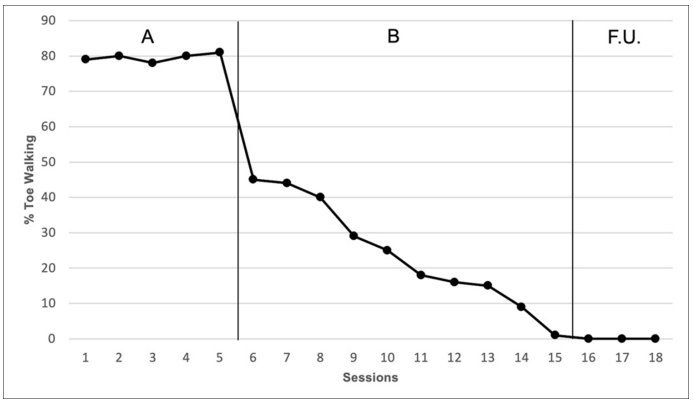

Figure 2: Experimental design AB for the treatment of Matteo's toe walking. Where A = Baseline, B = Intervention (DRA: Differential Reinforcement of Alternative Behaviours + Extinction), FU = Follow-Up (after one, two and three months).

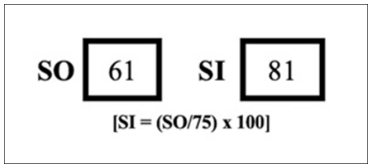

Figure 3: Giorgio's TWS severity index. The arithmetic sum of the item scores entered in the square with the highlighted sides of the TWS must be entered in the "SO" (Score Obtained) box, then divided by 75 (Maximum Score Obtainable) and multiplied by 100; the result entered in the "SI" (Severity Index) box expresses Giorgio's TW Severity Index, which is "VERY SEVERE", being > 80%.

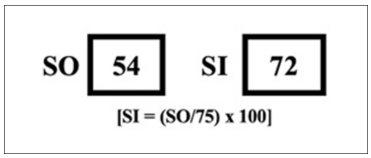

Figure 4: Mario's TWS severity index. The arithmetic sum of the item scores entered in the square with the highlighted sides of the TWS must be entered in the "SO" (Score Obtained) box, then divided by 75 (Maximum Score Obtainable) and multiplied by 100; the result entered in the "SI"

Name: _____GIORGIO_____ Age: _5,3 ___ Date: Maggio 2024_____

Diagnosis: _____ASD_____ Observer: ___////_____

Instructions: Below are some items describing the behaviour of some children who walk on tiptoes. Read the descriptions carefully and choose the answer you agree with most, then mark the number in the right-hand column of the sheet with a cross: "0" corresponds to "No, never", "1" to "Yes, sometimes" (1 to 5 times every 5 minutes, or for 2 minutes in a row, even with short intervals of 1-3 seconds), "2" to "Yes, often" (6 to 12 times every 5 minutes, or for 3 minutes in a row, even with short intervals of 1-3 seconds) and "3" corresponds to "Yes, always" (more than 12 times every 5 minutes, or more than 4 minutes in a row, even with short intervals of 1-3 seconds).

There are no right or wrong answers. Before answering, carefully observe the child's behaviour as described in the item. If you are unsure about a score, always choose the lowest one.

01. Shows difficulty interpreting sensory information (heat, cold, bright lights, noises, smells, handling objects, etc.), reacting excessively or insufficiently to stimuli	0	1	2	X	
02. Walks on tiptoes with or without shoes	0	1	2	X	
03. Walks on tiptoes on soft surfaces (e.g., sand, carpet, etc.)	0	1	2	X	
04. Adopts unusual postures (muscle stiffness, legs clamped together, shoulders raised, arms crossed, jaw clenched, fingers tense, rhythmic hand movements, etc.) in various contexts of life	0	1	2	X	
05. When placing their heels on the ground, they spread their legs apart, rotating their feet outwards	0	1	2	X	
06. In a supine position, pushes off with only the toes against the wall	X	1	2	3	
07. If someone tells them to walk properly, they place the entire sole of the foot on the ground for less than 20 seconds	0	X	2	3	
08. When standing on tiptoes, the distance between the heel and the ground is > 6 cm	0	1	2	X	
09. He stands on his toes in a static position, without performing any activity, on a hard surface for more than one minute	0	1	2	X	
10. He runs or jumps on his toes	0	1	2	X	
11. When sitting or leaning his back against the wall, he rests only his toes on the floor	X	1	2	3	
12. Walking on his toes occurs only at certain times (excitement, happiness, tiredness, etc.)	0	1	2	X	
13. Shows generalised difficulty in motor planning (coordination of movements)	0	1	2	X	
14. When moving, has difficulty keeping the head upright and in line with the torso (without leaning forward), looking straight ahead	0	1	2	X	
15. Has difficulty walking on uneven surfaces or riding a bicycle	0	1	X	3	
16. Walks on tiptoes on a hard surface (e.g., floor, road, etc.).	0	1	2	X	
17. Climbs and descends stairs on tiptoes.	0	1	X	3	
18. Remains standing on tiptoes even when engaged in an activity with an object placed on a table.	0	1	X	3	
19. Stands on tiptoes in a static position, without performing any activity, on a soft surface for more than one minute	0	1	2	X	
20. Has difficulty performing body movements effectively and accurately (throwing, grasping, balancing on one leg, fitting geometric shapes together, etc.)	0	1	X	3	
21. Walking on tiptoes is associated with self-stimulatory behaviours (rocking, waving hands, clapping hands or feet, pacing back and forth, etc.).	0	1	2	X	
22. Shows sensitivity to touch (discomfort or pain) and to stimuli that would not normally be painful (light touches, fabrics in contact with the skin, movement of air, etc.).	0	X	2	3	
23. Walking on tiptoes occurs mainly in moments of stress or cognitive/sensory overload (too many stimuli at once: information, noises, lights, interactions).	0	1	2	X	
24. Shows difficulty with balance and postural control.	0	1	2	X	
25. Walks and/or stands on tiptoes in different contexts (home, school, etc.).	0	1	2	X	61

Table 2: The Toe Walking Scale (TWS) administered to Giorgio.

Name: MARIO Age: 3,9 Date: Maggio 2024

Diagnosis: ASD Observer: //////

Instructions: Below are some items describing the behaviour of some children who walk on tiptoes. Read the descriptions carefully and choose the answer you agree with most, then mark the number in the right-hand column of the sheet with a cross: "0" corresponds to "No, never", "1" to "Yes, sometimes" (1 to 5 times every 5 minutes, or for 2 minutes in a row, even with short intervals of 1-3 seconds), "2" to "Yes, often" (6 to 12 times every 5 minutes, or for 3 minutes in a row, even with short intervals of 1-3 seconds) and "3" corresponds to "Yes, always" (more than 12 times every 5 minutes, or more than 4 minutes in a row, even with short intervals of 1-3 seconds).

There are no right or wrong answers. Before answering, carefully observe the child's behaviour as described in the item. If you are unsure about a score, always choose the lowest one.

01. Shows difficulty interpreting sensory information (heat, cold, bright lights, noises, smells, handling objects, etc.), reacting excessively or insufficiently to stimuli	0	1	2	X	
02. Walks on tiptoes with or without shoes	0	1	2	X	
03. Walks on tiptoes on soft surfaces (e.g., sand, carpet, etc.)	0	1	2	X	
04. Adopts unusual postures (muscle stiffness, legs clamped together, shoulders raised, arms crossed, jaw clenched, fingers tense, rhythmic hand movements, etc.) in various contexts of life	0	1	X	3	
05. When placing their heels on the ground, they spread their legs apart, rotating their feet outwards	0	1	X	3	
06. In a supine position, pushes off with only the toes against the wall	X	1	2	3	
07. If someone tells them to walk properly, they place the entire sole of the foot on the ground for less than 20 seconds	0	1	2	X	
08. When standing on tiptoes, the distance between the heel and the ground is > 6 cm	0	1	X	3	
09. He stands on his toes in a static position, without performing any activity, on a hard surface for more than one minute	0	1	2	X	
10. He runs or jumps on his toes	0	1	X	3	
11. When sitting or leaning his back against the wall, he rests only his toes on the floor	X	1	2	3	
12. Walking on his toes occurs only at certain times (excitement, happiness, tiredness, etc.)	0	1	2	X	
13. Shows generalised difficulty in motor planning (coordination of movements)	0	1	2	X	
14. When moving, has difficulty keeping the head upright and in line with the torso (without leaning forward), looking straight ahead	0	1	X	3	
15. Has difficulty walking on uneven surfaces or riding a bicycle	0	1	X	3	
16. Walks on tiptoes on a hard surface (e.g., floor, road, etc.).	0	1	2	X	
17. Climbs and descends stairs on tiptoes.	0	1	X	3	
18. Remains standing on tiptoes even when engaged in an activity with an object placed on a table.	0	1	X	3	
19. Stands on tiptoes in a static position, without performing any activity, on a soft surface for more than one minute	0	1	X	3	
20. Has difficulty performing body movements effectively and accurately (throwing, grasping, balancing on one leg, fitting geometric shapes together, etc.)	0	1	2	X	
21. Walking on tiptoes is associated with self-stimulatory behaviours (rocking, waving hands, clapping hands or feet, pacing back and forth, etc.).	0	X	2	3	
22. Shows sensitivity to touch (discomfort or pain) and to stimuli that would not normally be painful (light touches, fabrics in contact with the skin, movement of air, etc.).	0	X	2	3	
23. Walking on tiptoes occurs mainly in moments of stress or cognitive/sensory overload (too many stimuli at once: information, noises, lights, interactions).	0	X	2	3	
24. Shows difficulty with balance and postural control.	0	1	2	X	
25. Walks and/or stands on tiptoes in different contexts (home, school, etc.).	0	1	2	X	54

Table 3: The Toe Walking Scale (TWS) administered to Mario.

Name: _____MATTEO_____ Age: __3,2__ Date: __Maggio 2024_____

Diagnosis: ____ASD_____ Observer: _____//////_____

Instructions: Below are some items describing the behaviour of some children who walk on tiptoes. Read the descriptions carefully and choose the answer you agree with most, then mark the number in the right-hand column of the sheet with a cross: "0" corresponds to "No, never", "1" to "Yes, sometimes" (1 to 5 times every 5 minutes, or for 2 minutes in a row, even with short intervals of 1-3 seconds), "2" to "Yes, often" (6 to 12 times every 5 minutes, or for 3 minutes in a row, even with short intervals of 1-3 seconds) and "3" corresponds to "Yes, always" (more than 12 times every 5 minutes, or more than 4 minutes in a row, even with short intervals of 1-3 seconds).

There are no right or wrong answers. Before answering, carefully observe the child's behaviour as described in the item. If you are unsure about a score, always choose the lowest one.

01. Shows difficulty interpreting sensory information (heat, cold, bright lights, noises, smells, handling objects, etc.), reacting excessively or insufficiently to stimuli	0	X	2	3	
02. Walks on tiptoes with or without shoes	0	1	2	X	
03. Walks on tiptoes on soft surfaces (e.g., sand, carpet, etc.)	0	1	2	X	
04. Adopts unusual postures (muscle stiffness, legs clamped together, shoulders raised, arms crossed, jaw clenched, fingers tense, rhythmic hand movements, etc.) in various contexts of life	0	1	X	3	
05. When placing their heels on the ground, they spread their legs apart, rotating their feet outwards	0	X	2	3	
06. In a supine position, pushes off with only the toes against the wall	X	1	2	3	
07. If someone tells them to walk properly, they place the entire sole of the foot on the ground for less than 20 seconds	0	X	2	3	
08. When standing on tiptoes, the distance between the heel and the ground is > 6 cm	0	1	X	3	
09. He stands on his toes in a static position, without performing any activity, on a hard surface for more than one minute	0	1	X	3	
10. He runs or jumps on his toes	0	1	X	3	
11. When sitting or leaning his back against the wall, he rests only his toes on the floor	X	1	2	3	
12. Walking on his toes occurs only at certain times (excitement, happiness, tiredness, etc.)	0	X	2	3	
13. Shows generalised difficulty in motor planning (coordination of movements)	0	X	2	3	
14. When moving, has difficulty keeping the head upright and in line with the torso (without leaning forward), looking straight ahead	0	1	X	3	
15. Has difficulty walking on uneven surfaces or riding a bicycle	0	X	2	3	
16. Walks on tiptoes on a hard surface (e.g., floor, road, etc.).	0	1	2	X	
17. Climbs and descends stairs on tiptoes.	0	1	X	3	
18. Remains standing on tiptoes even when engaged in an activity with an object placed on a table.	0	X	2	3	
19. Stands on tiptoes in a static position, without performing any activity, on a soft surface for more than one minute	0	1	X	3	
20. Has difficulty performing body movements effectively and accurately (throwing, grasping, balancing on one leg, fitting geometric shapes together, etc.)	0	X	2	3	
21. Walking on tiptoes is associated with self-stimulatory behaviours (rocking, waving hands, clapping hands or feet, pacing back and forth, etc.).	0	X	2	3	
22. Shows sensitivity to touch (discomfort or pain) and to stimuli that would not normally be painful (light touches, fabrics in contact with the skin, movement of air, etc.).	0	X	2	3	
23. Walking on tiptoes occurs mainly in moments of stress or cognitive/sensory overload (too many stimuli at once: information, noises, lights, interactions).	0	X	2	3	
24. Shows difficulty with balance and postural control.	0	1	X	3	
25. Walks and/or stands on tiptoes in different contexts (home, school, etc.).	0	1	2	X	37

Table 4: The Toe Walking Scale (TWS) administered to Matteo.

(Severity Index) box expresses Mario's TW Severity Index, which is "SEVERE", as it is between 51% and 80%.

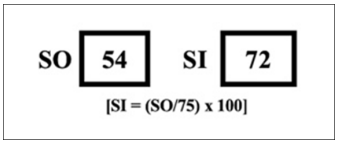

Figure 5: Matteo's TWS severity index. The arithmetic sum of the item scores entered in the square with the highlighted sides of the TWS must be entered in the "SO" (Score Obtained) box, then divided by 75 (Maximum Score Obtainable) and multiplied by 100; the result entered in the "SI" (Severity Index) box expresses Matteo's TW Severity Index, which is "MODERATE", as it is between 21% and 50%.

Conclusions

Toe walking, i.e. the tendency to walk, run or stand on tiptoes, is a behaviour that can occur in all individuals, with or without disabilities, up to approximately 3 years of age [6,16]. TW is present in 30% of individuals with autism spectrum disorder and, despite this incidence in the ASD population, there are no quantitative tools to assess it. Hence, the idea of the Toe Walking Scale (TWS) was developed with the aim of providing a useful quantitative tool for its assessment.

The study considered a sample of 102 subjects with autism, all of whom walked on their toes, had generalised dyspraxic problems and communication difficulties (several subjects used PECS or a communicator (tablet with specific software).

Conclusions

Toe walking, i.e. the tendency to walk, run or stand on tiptoes, is a behaviour that can occur in all individuals, with or without disabilities, up to approximately 3 years of age [6,16]. TW is present in 30% of individuals with autism spectrum disorder and, despite this incidence in the ASD population, there are no quantitative tools to assess it. Hence, the idea of the Toe Walking Scale (TWS) was developed with the aim of providing a useful quantitative tool for its assessment.

The study considered a sample of 102 subjects with autism, all of whom walked on their toes, had generalised dyspraxic problems and communication difficulties (several subjects used PECS or a communicator (tablet with specific software).

As can be seen from the cases presented, the TWS, in addition to being useful for clinical practice, could also support the rehabilitation of these children: there is very little data on the treatment of toe walking [28-30], and this lack of data could also be linked to the absence, until now, of quantitative tools to assess this behaviour. A tool such as TWS, for example, could guide rehabilitation practice by providing detailed information on the severity of the problem, based on which one intervention rather than another could be decided upon.

The scale has been designed to be understandable and easily administered by all practitioners; moreover, although it was constructed with reference to a small sample, it is nevertheless reliable due to the inter-observer agreement (IOA) that was achieved to reduce all possible internal and external variables. The data are encouraging but will need further confirmation through more observations obtained by expanding the sample under study.

References

1. Ghaziuddin M, Butler E. Clumsiness in autism and Asperger syndrome: a further report. J Intellect Disabil Res. 1998; 42: 43-48.
2. Noterdaeme M, Mildenberger K, Minow F, et al. Evaluation of neuromotor deficits in children with autism and children with a specific speech and language disorder. Eur Child Adolesc Psychiatry. 2002; 11: 219-225.
3. Fournier KA, Hass CJ, Naik SK, et al. Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. J Autism Dev Disord. 2010; 40: 1227-1240.
4. Memari AH, Ghanouni P, Shayestehfar M, et al. Postural control impairments in individuals with autism spectrum disorder: A critical review of current literature. Asian J Sports Med. 2014; 5: e22963.
5. Attias M, Bonnefoy-Mazure A, De Coulon G, et al. Toe-walking and its impact on first and second rocker in gait patterns with different degrees of artificially emulated soleus and gastrocnemius contracture. Gait Posture. 2023; 105: 104-109.
6. Ming X, Brimacombe M, Wagner G. Prevalence of motor impairment in autism spectrum disorders. Brain Dev. 2007; 29: 565-570.
7. Liu T. Motor milestone development in young children with autism spectrum disorders: An exploratory study. Educational Psychology in Practice. 2012; 28: 315-326.
8. Bedford R, Pickles A, Lord C. Early gross motor skills predict the subsequent development of language in children with autism spectrum disorder. Autism Res. 2016; 9: 993-1001.
9. Calhoun M, Longworth M, Chester VL. Gait patterns in children with autism. Clin Biomech (Bristol). 2011; 26: 200-206.
10. Kindregan D, Gallagher L, Gormley J. Gait deviations in children with autism spectrum disorders: A review. Autism Res Treat. 2015; 741480.
11. Biffi E, Costantini C, Ceccarelli SB, et al. Gain pattern and motor performance during discrete gait perturbation in children with autism spectrum disorders. Front Psychol. 2018; 9: 2530.
12. Ruzbarsky JJ, Scher D, Dodwell E. Toe walking: Causes, epidemiology, assessment and treatment. Curr Opin Pediatr. 2016; 28: 40-46.
13. Van Kuijk AA, Kosters R, Vugts M, et al. Treatment for idiopathic toe walking: A systematic review of the literature. J Rehabil Med. 2014; 46: 945-957.
14. Accardo PJ, Whitman B. Toe walking A marker for language disorders in the developmentally disabled. Clin Pediatr (Phila). 1989; 28: 347-350.

15. Accardo P, Morrow J, Heany MS, et al. Toe walking and language development. Clin Pediatr (Phila). 1992; 31: 158-160.
16. Barrow WJ, Jaworski M, Accardo PJ. Persistent toe walking in autism. J Child Neurol. 2011; 26: 619-621.
17. Engström P, Tedroff K. Idiopathic Toe-Walking: prevalence and natural history from birth to ten years of age. J Bone Joint Surg Am. 2018; 100: 640-647.
18. Shetreat-Klein M, Shinnar S, Rapin I. Abnormalities of joint mobility and gait in children with autism spectrum disorders. Brain Dev. 2014; 36: 91-96.
19. Valagussa G, Trentin L, Signori A, et al. Toe walking assessment in autism spectrum disorder subjects: a systematic review. Autism Res. 2018; 11: 1404-1415.
20. Bodfish JW, Symons FJ, Parker DE, et al. Varieties of repetitive behavior in autism: comparisons to mental retardation. J Autism Dev Disord. 2000; 30: 237-243.
21. Radonovich KJ, Fournier KA, Hass CJ. Relationship between postural control and restricted, repetitive behaviors in autism spectrum disorders. Front Integr Neurosci. 2013; 7: 28.
22. Uljarevic M, Hedley D, Alvares GA, et al. Relationship between early motor milestones and severity of restricted and repetitive behaviors in children and adolescents with autism spectrum disorder. Autism Res. 2017; 10: 1163-1168.
23. Accardo PJ, Barrow WJ. Toe walking in autism: Further observations. J Child Neurol. 2015; 30: 606-609.
24. Skinner BF. Superstition in the pigeon. J Exp Psychol Gen. 1992; 121: 273-274.
25. Sundberg ML. VB-MAPP. Verbal Behavior Milestones Assessment and Placement Program. Concord, CA: AVB Press.
26. Guazzo GM. L'Aba in azione. Roma: Anicia. 2021.
27. Zapata KA, Trevino ME, Reyes FI, et al. Adherence to serial casting protocols for idiopathic toe walking: A quality improvement initiative. J Pediatr Rehabil Med. 2022; 15: 469-476.
28. Marcus A, Sinnott B, Bradley S, et al. Treatment of idiopathic toe-walking in children with autism using GaitSpot Auditory Speakers and simplified habit reversal. Research in Autism Spectrum Disorders. 2010; 4: 260-267.
29. Persicke A, Jackson M, Adams AN. Brief report: An evaluation of TAGteach components to decrease toe-walking in a 4-year-old child with autism. J Autism Dev Disord. 2014; 44: 965-968.
30. Wilder DA, Ertel H, Hodges AC, et al. The use of auditory feedback and edible reinforcement to decrease toe walking among children with autism. J Appl Behav Anal. 2019; 53: 554-562.