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Feasibility and acceptability of using wearable sensors to quantify tip toe behavior in individuals with severe autism spectrum disorder: preliminary results

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BACKGROUND AND OBJECTIVES

Toe walking is a clinical motor sign present in 20% of individuals with autism spectrum disorder (ASD). Because this behavior is also found during standing or running, the term tip-toe behavior (TTB) seems to be more appropriate[1].
A systematic review found a lack of studies that quantify TTB in individuals with ASD[2].
The most used and reliable instrumental tool to quantify motor deficit during standing and walking is optoelectronic or wearable gait analysis, but this approach requests the positioning of a large number of markers/devices on the skin of the patient, a long time to prepare the patient for the execution of the test and a non-ecological setting for the trials. For all these reasons, these methodologies find difficult application with individuals with severe ASD because of their non acceptance. Thus, a simpler instrumental approach with not obtrusive wearable sensors usable in an ecological setting could be a useful resource to quantify TTB in individuals with severe ASD.
Objectives: The aims of this pilot study are:
1) to verify the acceptability of wearable sensors in individuals with severe ASD;
2) to verify the feasibility of TTB quantification using wearable sensors during structured standing and walking tasks.

MATERIALS AND METHODS

- Subjects with ASD diagnosed according to DSM-5 criteria and confirmed using the Autism Diagnostic Observation Schedule were admitted to the study. Three individuals (10.9 years, 12.8 years and 13 years, 3/3 males, and ADOS CSS 9, 10 and 8, respectively) with severe ASD and TTB were assessed.
- TTB was quantified using "Sensoria® Smart Socks" (SSS), a commercially available wireless gait monitoring technology (Figure 1). SSS was found a valid measure instrument in a previous study[3].
- To assess the TTB quantity during standing and walking we used a static and dynamic test following the methodology proposed in a previous study[4] (Figure 2).
- The static test consisted in playing while standing in front of a table for 3 minutes.
- The dynamic test consisted in transporting 1 object (puzzle, Lego®, …) from the therapist to the playing table placed 2 meters away and back again 15 times. The test was conducted without shoes albeit with SSS.
- The same person was tested three times on three different days (total of 9 acquisitions).
- The data acquired from the SSS were elaborated from a dedicated algorithm to detect and measure TTB steps vs heel contact steps (figure 2).
- The result of the dynamic test is presented as the mean percentage number of toe steps and the result of the static test is reported as the mean percentage of seconds in TTB.

Figure 1. Sensoria® Smart Socks

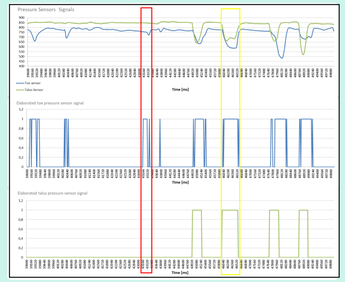

Figure 3. Example of acquired and elaborated signals. The red square identify a tip-toe step and the yellow square identify a step with a heel contact.

Static test: time spent in TTB during a static task

Dynamic Test: number of TTB steps during a dynamic task

Figure 2. Static and dynamic tests

RESULTS

✓ We found that SSS approach was feasible and acceptable in the individuals with severe ASD and TTB in all three trials.
✓ We were also able to quantify TTB during both the static and the dynamic tests using the SSS tool in 9/9 of the acquisition (100%) (example in Figure 3).

CONCLUSIONS

- "Sensoria® Smart Socks" seems to be a **feasible and acceptable** wearable sensors approach for quantifying TTB in individuals with severe ASD and TTB. Further research is required to confirm these preliminary results.

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