APPENDIX: SUMMARY OF SELECTED TURNING ALGORITHMS USING WEARABLE INERTIAL SENSORS*

| Authors | Sensor Location Used to Analyses a Turn | Number of Subjects | Protocol | Expected Turn Angle | Turn Metrics Used | Accuracy of Turn Angle (°) Estimation |
|---|---|---|---|---|---|---|
| Fleury et al. [13] (2007) | Upper trunk | HC: n = 8 | Walk back and forth with ten 180° turn<br>Walk, go up and down the stairs and make four 180° turn and eight 90° turn | 180°<br>90° | Turn angle (°) | Not provided;<br>Representative figure only |
| Higashi et al. [14] (2008) | Lumbar and Thigh | HC: n = 10<br>Hemiplegic: n = 20 | 3-meter Timed Up and Go (TUG) | 180° | Turn duration (s) | Not provided |
| Salarian et al.[3] (2009) | Sternum and Shank | PD: n =12<br>HC: n = 14 | 7 meter walk straight, turn and return back to original position X 3 times | 180° | Peak angular velocity (°/s)<br>Turn duration (s)<br>Number of steps in turn (#)<br>Average step time (s)<br>Maximum step time (s)<br>Step before the turn (s)<br>Number of double steps (#) | Not provided |
| Mariani et al. [4] (2010) | Feet | Young HC: n = 10<br>Elderly HC: n = 10 | 5-meter U-shaped walking task<br>Figure 8-shaped walking task, and<br>6-min walking task | 180° and continuous turns range from -150° to 150° | Turn angle (°) | Validated against optical motion capture<br>For 180° turn: 1.6 ± 6.1° (mean Accuracy ± precision) |
| Weiss et al. [15] (2013) | Lumbar | With IADL (Instrumented Activity of daily living disability): n=52<br>Without IADL: n=177 | Timed Up and Go (TUG) | 180° | Peak angular velocity (°/s)<br>Turn duration (s)<br>Number of steps in turn (#)<br>Range of acceleration (g) | Not provided |
| Mariani et al. [16] (2013) | Feet | PD: n=10 (ON and OFF states)<br>HC: n=10 | 3-meter Timed Up and Go (TUG) | 180° | Turn duration (s)<br>Turn angle (s) | Validated against optical motion capture<br>0.12 ± 3.59° (Accuracy ± precision) |
| El-Gohary et al. [1] (2014) | Lumbar | Lab: PD: n=21<br>HC: n=19<br>Home: PD: n=12<br>HC: n=18 | Lab: Pre-planned turns with different directions and angles (slow, self-preferred, and fast pace)<br>Home: A week of daily activities | Lab: 45°<br>90°<br>135°<br>180°<br>Home: Free-living | Number of turns (#)<br>Peak angular velocity (°/s)<br>Mean angular velocity (°/s)<br>Turn duration (s) | Not provided |
| Novak et al. [17] (2014) | Head<br>Upper back<br>Lower back<br>Thigh<br>Shank<br>Foot | HC: n=10<br>Amputee: n=1 | Pre-planned turns with different directions and angles | 22°<br>45°<br>90° | Turn onset (ms)<br>Turn direction (±)<br>Turn angle (°) | Not provided |
| Nguyen et al. [18] (2015) | Sternum | HC: n = 16 | 10-meter Timed Up and Go (TUG) X 2 times | 180° | Walk-to-Turn transition (ms)<br>Turn-to-Walk transition (ms)<br>Turn-to-Stand transition (ms) | Not provided |
| Fino et al. [19] (2015) | Sternum and Shank | HC: n = 5 | Pre-planned turns with 90° (slow, self-preferred, and fast pace) and four obstacle heights | 90° | Step vs spin turns (#) | Not provided |
| Beyea et al.[6] (2017) | Sternum | HC: n = 11 | 3- and 5-meter Timed Up and Go (TUG) X 3 times (with normal and slow speed) | 180° | Turn duration (s) | Not provided |
| Pham et al. [2] (2017) | Lumbar | PD: n = 25 (both, ON and | 90 min consisted of daily activity-like procedures, | Free-living | Turn onset (ms)<br>Turn direction (±) | Validated against video<br>Two clinical observers |

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| | | OFF states)<br>HC: n = 14 | such as walking in the rooms and corridors of the lab environment without restriction, opening and closing doors, climbing stairs, performing transfers such as sit-to-stand, sit-to-walk, stand-to-sit, and walk-to-sit, brushing teeth, making coffee, drinking a cup of tea, and ironing | | Turn duration (s)<br>Turn angle (°) | rated every vertical rotation ≥ 45° as a turn<br>ICC with the clinical score: 0.92<br>Turn angle: 0.06 ± 014° (mean error ± SEM)<br>Turn angle error is the difference in turning angle from observers and algorithm |
| Bertoli et al. [7] (2017) | Lumbar | PD-FOG: n = 25<br>PD-nFOG: n = 18 | 2-min walk with 180° turns<br>1-min turn in-place (alternative 360° turning in the opposite direction) | 180°<br>360° | Turn duration (s)<br>Peak angular velocity (°/s)<br>Turn Jerk ($g^2$/s)<br>Turn range (g) | Not provided |
| Haertner et al. [8] (2018) | Lumbar | PD: n = 43<br>Vigorous (n=18): no fear of fall (FOF) + no fall history<br>Anxious (n=12): with FOF + no fall history<br>Stoic (n=8): no FOF + with fall history<br>Aware (n=5): with FOF and fall history | Lab: 7-meter Timed Up and Go (TUG)<br>Home: Median of 12 days of continuous monitoring | Lab:180°<br>Home: Free-living | Turn duration (s)<br>Turn angle (°)<br>Average angular velocity (°/s)<br>Peak angular velocity (°/s)<br>Start angular velocity (°/s)<br>Middle angular velocity (°/s)<br>End angular velocity (°/s) | Lab (same as Pham et al. 2017 [2]):<br>iTUG<br>Vigorous: 183 ± 7 °<br>Anxious: 178 ± 9 °<br>Stoic: 181 ± 4 °<br>Aware: 172 ± 12 °<br>Home: Not provided (Slight change to Pham et al. 2017 [2]) |
| Meghji et al. [9] (2019) | Sternum (over the mid-point of the thoracic vertebrae (T4 to T6)) | Recreational male athletes: n = 6 | Pre-planned turns with different directions and angles X 5 times | 45°<br>90°<br>135°<br>180° | Turn angle (°) | Left turn (mean ± SD):<br>43.6 ± 1.7 °<br>89.0 ± 2.5 °<br>135.3 ± 2.8 °<br>180.3 ± 4.4 °<br>Right turn (mean ± SD):<br>44.7 ± 2.0 °<br>90.4 ± 3.4 °<br>133.5 ± 3.3 °<br>183.1 ± 3.5 ° |
| Hsieh et al. [17] (2019) | Lumbar | HC: n=5<br>Knee osteoarthritis: n=5 | 5-meter and 10-meter TUG X 3 times | 180° | Turn duration (s) | Not provided |
| Ortega-Bastidas et al. [18] (2019) | Lumbar | Young HC: n = 25<br>Elderly HC: n = 12 | 3-meter TUG X 3 times | 180° | Steps in a turn (#)<br>Mean angular velocity (°/s) | Not provided |
| Rehman et al. [12] (2020) | Head<br>Neck<br>Lumbar<br>Ankles | HC: n = 56<br>PD: n = 37 | Straight walk along 10-meter instrumented walkway X 4 times | 180° | Turn angle (°)<br>Turn duration (s)<br>Number of turns (#)<br>Peak angular velocity (°/s)<br>Mean angular velocity (°/s)<br>[an additional 420 measures] | Validated against video<br>ICC between the rater and algorithm ≥0.99 for start and end of a turn.<br>Lumbar:<br>HC: 172.59 ± 22.99°<br>PD: 168.37 ± 29.33°<br>Neck:<br>HC: 105.35 ± 25.05°<br>PD: 92.65 ± 31.50°<br>Head:<br>HC: 134.51 ± 29.76°<br>PD: 138.32 ± 32.34° |

*only includes manuscripts in which a new approach to detect a turn using inertial sensors automatically is presented and does not include manuscripts in which an already published algorithm was used or in which a turn was detected manually.