Capability of accelerometers in wearable devices for measurement of postural tremor, gait and balance, and nocturnal scratching

Kelly, PJ[a], Cohen, A[a], Ellis, RD[a]

[a] Koneksa Health, Inc.

Introduction

- Motor symptoms in patients with movement disorders are traditionally measured using clinician and patient reported outcome measures such as the MDS-UPDRS[1].
- Consumer devices, such as smartphones and smartwatches, are becoming increasingly popular for use in clinical trials. The use of accelerometers within such devices may offer an opportunity to do precise measurement of upper body postural tremor, gait and balance, and nocturnal scratching.
- The accelerations associated with gait and balance are typically of magnitude 0.1g and above[2], whereas those for postural tremor and nocturnal scratching can be as low as 0.005g and 0.02g respectively[3,4].
- To determine whether 3 devices:
  - iPhone XR[5]
  - Apple Watch Series 5[6]
  - ActiGraph GT9X Link[7]

  might be suitable for digital measurement of these symptoms, we analyzed the sensitivity of their accelerometers to determine their ability to measure accelerations observed in the symptoms of interest.

Method

- A Quanser Shake Table II[8] was used to oscillate the three devices across a range of frequencies and amplitudes representative of postural tremor, gait and balance, and nocturnal scratching.
- The frequency ranged from 0.5 Hz to 10 Hz and the amplitude from 0.01 cm to 6 cm, corresponding to an acceleration range of 0.005g to 2g. Each amplitude/frequency combination was tested 3 times.
- The degree of agreement, as measured by the intraclass correlation coefficient (ICC), between the output of each device and the reference acceleration of the Shake Table (taken as the gold standard) was assessed. The median ICC across the 3 tests of each amplitude/frequency combination was calculated for each device.
- ICC values greater than 0.90 are considered excellent, between 0.75 and 0.9 good, between 0.5 and 0.75 moderate, and less than 0.5 considered poor[9].

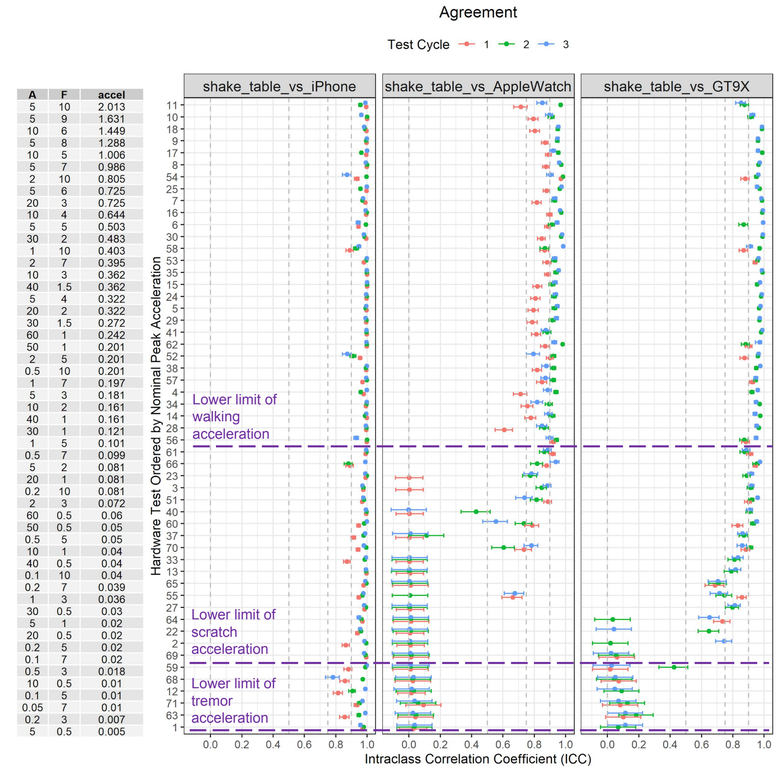
Results

- iPhone XR:
  - agreement is excellent or good for the full range of accelerations tested (median ICC values for each amplitude/frequency combination in range 0.86 to 1)
- Apple Watch Series 5:
  - for peak acceleration >= 0.07g, agreement is excellent or good (median ICC values in range 0.77 to 0.97);
  - below 0.07g, agreement is moderate or poor (median ICC values in range 0 to 0.74)
- ActiGraph GT9X Link:
  - for peak acceleration >= 0.04g, agreement is excellent or good (median ICC values in range 0.88 to 0.96);
  - below 0.04g, agreement is moderate or poor (ICC values in range 0.03 to 0.75)

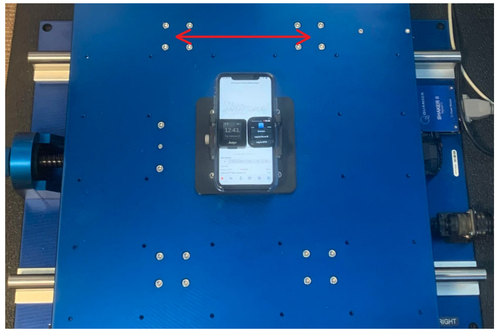
Conclusions

- The Apple Watch Series 5 and ActiGraph GT9X Link are suitable (with good or excellent agreement) for measuring the accelerations associated with gait and balance.
- The Apple Watch Series 5 and ActiGraph GT9X Link are not capable of measuring the full range of accelerations associated with postural tremor and nocturnal scratching, with only poor or moderate agreement at the lower end of the range of interest.
- The iPhone XR accelerometer is suitable (with good or excellent agreement) for measuring the full range of accelerations associated with postural tremor, gait and balance, and nocturnal scratching. (The practicalities of using a smartphone to measure nocturnal scratching are beyond the scope of this study.)

A	F	accel
5	10	2.013
5	9	1.631
10	6	1.449
5	8	1.288
10	5	1.006
5	7	0.986
2	10	0.805
5	6	0.725
20	3	0.725
10	4	0.644
5	5	0.503
30	2	0.483
1	10	0.403
2	7	0.395
10	3	0.362
40	1.5	0.362
5	4	0.322
20	2	0.322
30	1.5	0.272
60	1	0.242
50	1	0.201
2	5	0.201
0.5	10	0.201
1	7	0.197
5	3	0.181
10	2	0.161
40	1	0.161
30	1	0.121
1	5	0.101
0.5	7	0.099
5	2	0.081
20	1	0.081
0.2	10	0.081
2	3	0.072
60	0.5	0.06
50	0.5	0.05
0.5	5	0.05
10	1	0.04
40	0.5	0.04
0.1	10	0.04
0.2	7	0.039
1	3	0.036
30	0.5	0.03
5	1	0.02
20	0.5	0.02
0.2	5	0.02
0.1	7	0.02
0.5	3	0.018
10	0.5	0.01
0.1	5	0.01
0.05	7	0.01
0.2	3	0.007
5	0.5	0.005



ICC values for each combination of amplitude (A) in mm, frequency (F) in Hz, and acceleration (accel) in g. Each combination was run 3 times.



Shake Table with the 3 devices attached.
Arrow indicates direction of movement.

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