Scikit Digital Health for Accelerometry Physical Activity: Comparisons to Existing Solutions and Investigations of Age Effects in Healthy Adults

Sheraz Khan on behalf of all authors

SciKit digital health package for accelerometry-measured physical activity: comparisons to existing solutions and investigations of age effects in healthy adults

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Wrist-based Physical Activity Metrics

Background

- Using body acceleration (typically wrist) to estimate frequency, duration, and intensity of physical activity
- Previous lit has focused on 4 categories of physical activity, thresholds usually defined by Metabolic Equivalent of Task (MET)
 - Easy to interpret
 - Easy to calculate
- Thresholds vary from study-to-study based on population, activities performed, etc
- More recent work has focused on non-threshold based approaches, or fragmentation of the activity categories

Physical Activity Categories

• **Sedentary**: ~<1.5 MET – sitting, lying down



- *Light*: ~1.6 3.0 MET slow walking, standing in lines
- Moderate: ~3.0 6.0 MET walking briskly, household chores
- Vigorous: ~>6.0 MET running, exercise, hard/physical chores





In-house implementation removes device as a factor

Current Actigraphy Space

- Existing solutions:
 - GeneActiv Macros
 - GGIR
 - ActiGraph
 - pyActigraphy
 - Digital Biomarker Discovery Pipeline
- In-house solution: SKDH
 - Integrated with processing pipelines
 - Full control over algorithm/processing steps
 - Device agnostic (IO for devices we use!)









Physical Activity Algorithm

Processing Steps

- Accelerometer calibration [optional]
- Wear detection [optional]
- Sleep analysis [optional]
- Physical activity analysis
 - For each day:
 - Exclude non-wear & sleep if available
 - Compute Euclidean Norm Minus One
 - Compute physical activity metrics





Validation against existing algorithms and application in healthy adults

Validation

- No "ground truth" available
- Compare SKDH implementation to existing algorithms using STRYDE¹ (sensors to record your daily exercise) dataset
- GeneActiv Macros
 - Different accel. accumulation/summary
 - Activity classification per minute
- GGIR
 - Very close implementation
 - Accel. accumulation & thresholds matched to SKDH
- Subset of physical activity metrics compared based on available metrics

Application

- Explore STRYDE study age-group differences from activity metrics
- Explore age effects in activity effects

STRYDE demographics

	Younger	Older
Ν	33	32
F/M	17/16	16/16
Age (years)	29.2±4.6	72.3±5.8

¹Czech et al. Age and environment-related differences in gait in healthy adults using wearables. *npj Digit Med.* (2020)

Definitions

Standard

- ENMO: Euclidean Norm Minus One acceleration magnitude less gravity
- Sedentary: 0-1.5 MET, ENMO < 0.05g*
- Light: *1.6-3.0 MET*, 0.05g* ≤ ENMO < 0.11g*
- Moderate: 3.0-6.0 MET, $0.11g^* \le ENMO < 0.44g^*$
- Vigorous: >6.0 MET, ENMO \geq 0.44g*
- SLPA: Sedentary & light physical activity
- MVPA: moderate & vigorous physical activity
- **Maximum acceleration**: the maximum observed acceleration in windows of *X* length
- * SKDH & GGIR, GeneActiv has its own thresholds

Non-Standard/Fragmentation

- Intensity Gradient: Slope (log-log) of decreasing time spent in higher physical activity levels (bins of 0.025g)
- Average Duration: The average duration spent at a particular intensity.
- **Transition Probability**: The likelihood to transition out of a particular activity intensity. Math works out to be the inverse of the average duration



Intensity Gradient Examples



SKDH Validation Results: Generally good to excellent agreement with existing algorithms.

Table 1: Comparisons of mean activity metrics across days between SKDH and references (GGIR / GENEActiv Macros) for selected activity metrics.

Package	Metrics	ICC (95% CI)	Mean Diff. (p-value*)	Corr. (p-value)
GGIR	Intensity Gradient	$0.941 \ (0.048, 0.986)$	-0.083 (<0.001)	0.989 (<0.001)
	MVPA Time	$0.997 \ (0.991, 0.999)$	$1.900 \ (< 0.001)$	$0.998 \ (< 0.001)$
	Sedentary Time	$0.550 \ (0.356, 0.699)$	-2.299(0.8162)	0.547 (< 0.001)
	Light Time	$0.995 \ (0.991, 0.997)$	$0.968\ (0.0315)$	0.995~(<0.001)
	Moderate Time	$0.997 \ (0.996, 0.998)$	$0.748\ (0.0472)$	$0.998 \ (< 0.001)$
	Vigorous Time	$1.000 \ (1.000, 1.000)$	-0.001 (0.9393)	$1.000 \ (< 0.001)$
GENEActiv Macros	Sedentary Time	0.530 (-0.056,0.793)	-76.517 (<0.001)	0.733 (<0.001)
	Light Time	0.469 (-0.032, 0.813)	$-45.040 \ (<0.001)$	$0.957 \ (< 0.001)$
	Moderate Time	0.618 (-0.067, 0.880)	$48.954 \ (<0.001)$	$0.947 \ (< 0.001)$
	Vigorous Time	$0.697 \ (0.452, 0.828)$	3.233~(<0.001)	0.812 (< 0.001)
	Max. Acc. 15min	_t	_†	0.967 (< 0.001)

* *p*-values were computed from paired t-tests.

[†] Incompatible units: the acceleration summaries are different in units therefore the ICC and mean difference are not appropriate to be calculated;

Max. Acc: Maximum acceleration

Key Points

- Majority correlations are high
- GGIR ICC values are mostly high
- GENEActiv ICC values are moderate/good
 - Driven by different accel. Accumulation & thresholds
- Poor Sedentary time likely driven by different sleep calculations



Age effects are observed on select physical activity metrics

Key Points

Table 2: The Association Between Age and SKDH-Derived Physical Activity Metrics

- Time spent in moderate and MVPA showed strongly significant age group differences, vigorous showed significance
- Time spent in sedentary and light activity levels showed no significant age group differences
- Novel metrics such as Intensity Gradient and transition probabilities between activity levels showed showed significant age group differences

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	Group Mean (SD)				
	Younger	Older	Cohen's $d $	<i>p</i> -value (mean)	p-value (slope)
SLPA Trans. Prob.	$0.04\ (0.01)$	$0.02 \ (0.01)$	1.68	< 0.001	0.409
Intensity Gradient	-2.32(0.18)	-2.58(0.23)	1.27	< 0.001	0.017
MVPA Time [min]	$98.37\ (36.56)$	57.63(30.88)	1.22	< 0.001	0.130
Moderate Time [min]	$93.08\ (35.76)$	55.58(28.96)	1.17	< 0.001	0.167
Max. Acceleration 6min [g]	0.32(0.14)	$0.20 \ (0.09)$	1.04	< 0.001	0.185
IG Intercept	$13.48\ (0.79)$	$14.25\ (0.76)$	1.00	< 0.001	0.153
Max. Acceleration 15min [g]	0.24(0.11)	$0.16\ (0.08)$	0.87	0.001	0.076
Vigorous Time [min]	5.29(7.61)	2.05(3.26)	0.56	0.030	0.332
MVPA Trans. Prob.	0.43(0.11)	0.51 (0.20)	0.54	0.038	< 0.001
Sedentary Time [min]	708.40 (82.29)	732.94(86.79)	0.29	0.247	0.095
Light Time [min]	$118.27\ (25.36)$	118.89 (41.09)	0.02	0.942	0.180

Variation in physical activity metrics with age differs between younger and older cohorts

Key Points

- Age has different effects for younger and older groups
- Shown most prominently in
 - Intensity Gradient
 - Many SLPA/MVPA fragmentation endpoints such as transition probabilities

Group Mean (SD) Younger Older |Cohen's d| p-value (mean) *p*-value (slope) SLPA Trans. Prob. 0.02(0.01)0.04(0.01)1.68< 0.0010.409Intensity Gradient -2.58(0.23)1.27< 0.001-2.32(0.18)0.017MVPA Time [min] 98.37(36.56)57.63(30.88)1.22< 0.0010.130Moderate Time [min] 93.08 (35.76) 55.58(28.96)1.17< 0.0010.167Max. Acceleration 6min [g] 0.32(0.14)0.20(0.09)1.04< 0.0010.185IG Intercept 13.48(0.79)14.25(0.76)1.00< 0.0010.153Max. Acceleration 15min [g] 0.24(0.11)0.16(0.08)0.870.0010.076Vigorous Time [min] 2.05(3.26)0.3325.29(7.61)0.560.030MVPA Trans. Prob. 0.43(0.11)0.51(0.20)0.540.038< 0.001Sedentary Time [min] 708.40 (82.29) 732.94 (86.79) 0.290.2470.095Light Time [min] 118.27(25.36)118.89(41.09)0.020.9420.180



Table 2: The Association Between Age and SKDH-Derived Physical Activity Metrics

Probability to transition from Sedentary/Light PA zone is significantly different between age groups

Key Points

- Clear group separation/group difference
- Slopes relatively similar (p-value=0.409)





Probability to transition from Moderate-to-Vigorous PA zone is significantly different between age groups

Key Points

- Still significant age difference, if not as strong
- Highly significant difference in age effects between younger and older group (p-value<0.001)







Intensity gradient shows age effects, and age-related decline in the older cohort



Key Points

- Clear age separation/group difference
- Slope of older group is significantly steeper (p-value=0.017), indicating faster decline

Intensity Gradient: Change in time spent in higher physical activity levels

Future Avenues for Work

- Include pediatric population studies
- Include patient populations
- Healthy/patient comparisons, especially with fragmentation endpoints
- Additional non-threshold based metrics





Key Take-aways

- SKDH computes comparable activity metrics to existing packages providing a **device agnostic solution** to extract activity parameters from wrist sensors
- Select SKDH activity metrics such as time spent in MVPA and moderate activity as well as transition from different activity levels differ significantly between younger/older healthy adults
- Select activity metrics such as the change in time spent in higher physical activity levels vary differently with age in the younger and older groups



Thank You

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Thanks to whole DSTI team

Check for updates

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