INTRODUCTION: In order to obtain accurate estimates of sedentary time and physical activity in young children objective methods are needed. Wrist worn accelerometers have shown good feasibility among participants in previous studies. The acceleration signal collected by many commercially available activity monitors is usually summarized in an arbitrary unit (counts). Calibration studies are needed to translate activity counts into intensity categories. The placement of the activity monitor may affect the output, thus affecting the validity of the measurement. PURPOSE: The aim was to calibrate the Actigraph GT3X+ accelerometer for wrist worn placement in ambulatory young preschoolers by developing intensity thresholds for sedentary, low and high physical activity. Furthermore, to cross-validate the developed thresholds in a sample of young preschoolers and apply the developed thresholds on a sample of free living two year old children. METHODS: Wrist worn Actigraph GT3X+ was used to measure physical activity during 30 minutes of structured activities and free play in 38 children (15-36 months). Activity was video recorded and scored based on Children’s Activity Rating Scale (CARS) and combined with accelerometer data on a five second level. To develop intensity thresholds for sedentary, low and high physical activity ROC analysis was performed on data from 26 randomly selected children. The remaining 12 children were used for cross-validation. We applied the developed thresholds on data from 20 free-living children who wore an Actigraph on the wrist for 7 consecutive days. RESULTS: Optimal thresholds for sedentary were ≤89 Y-counts and ≤221 VM-counts/5 sec. Optimal thresholds for high physical activity were ≥440 Y-counts and ≥730 VM-counts/5 sec. Sensitivity and specificity was the same for the Y-axis and VM. Sensitivity for the sedentary threshold was 100% and specificity 60%. For the high physical activity threshold sensitivity was 60% and specificity 92,3%. Strong correlations were found between the developed thresholds for the accelerometer and CARS scoring time in sedentary, low and high intensity physical activity. Free-living children were categorized as sedentary for 384 (SD 70,3); low physical activity for 307 (SD 45,7) and engaged in high physical activity for 89 (SD 33,7) minutes per day. CONCLUSION:A wrist mounted Actigraph GT3X+ activity monitor can accurately assess sedentary behavior and different levels of physical activity in young preschoolers.
INTRODUCTION: Day-to-day patterns of habitual physical activity (PA) have been widely examined. Unlike PA, there is less evidence describing day-to-day variability in sedentary behavior (SB). PURPOSE: To determine if there are day-to-day differences in SB in adults and adolescents. METHODS: Forty-six adults (age=45.1±16.1 years) and 35 adolescents (age=14.3±1.4 years) wore an activPAL for 7-days. SB was computed from activPAL as percent of monitor wear time spent sedentary (%SED). Linear mixed effect models were used to test for differences in %SED across the seven days and between weekdays and weekend days. Independent t-tests were used to test for differences in the coefficient of variation (CV) between individuals with higher sedentary time (≥ 50th percentile of group) and individuals with lower sedentary time (<50th percentile of group). Separate analyses were conducted for adults and adolescents. Statistical significance was set at p<0.05. RESULTS: There were no significant differences in %SED between any of the seven days in adults and adolescents. %SED was similar between weekday and weekend days for both adults and adolescents. A significant difference in mean CV was observed between the group with higher sedentary time (adults=11.4±5.07%; adolescents=11.3±3.87%) and the group with lower sedentary time (adults=18.2±9.03%; adolescents=18.0±6.92%)

Table 1. Mean (SD) %SED by day of the week

<table>
<thead>
<tr>
<th></th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>65.1</td>
<td>65.6</td>
<td>65.4</td>
<td>64.4</td>
<td>61.5</td>
<td>63.1</td>
<td>62.7</td>
</tr>
<tr>
<td></td>
<td>(13.49)</td>
<td>(13.01)</td>
<td>(13.79)</td>
<td>(15.52)</td>
<td>(15.97)</td>
<td>(16.25)</td>
<td>(16.66)</td>
</tr>
<tr>
<td>Adolescent</td>
<td>68.4</td>
<td>66.0</td>
<td>66.5</td>
<td>68.0</td>
<td>66.7</td>
<td>66.2</td>
<td>65.3</td>
</tr>
<tr>
<td></td>
<td>(11.41)</td>
<td>(12.82)</td>
<td>(12.10)</td>
<td>(11.44)</td>
<td>(14.41)</td>
<td>(10.58)</td>
<td>(13.81)</td>
</tr>
</tbody>
</table>

CONCLUSION: These data demonstrate SB is stable day-to-day in adults and adolescents. One important finding was that type of day (weekday vs. weekend) did not influence SB. A second finding was that individuals who were more sedentary had lower day-to-day variability in SB. Both of these findings were in contrast to previous data on PA where weekday PA was significantly higher than weekend PA and day-to-day variability in PA was higher with increasing levels of PA. Our data suggest that SB and PA each have their own unique measurement characteristics. Further analyses are required to determine the minimum number of days to reliably estimate habitual SB.

Supported by NIH R01 NR011477
INTRODUCTION: Assessing time spent in different activity types may be important for early detection of mobility limitations in older adults. To date, accelerometer-based activity type prediction using machine learning algorithms have not been validated for this segment of the population. Therefore, the aim of this study was to use Random Forest (RF) models to predict activity type from accelerometer data in older adults. METHODS: Thirty-five healthy older adults (mean ± SD age = 70.8 ± 4.9 years) wore 3 ActiGraph GT3X + accelerometers. The monitors were initialized to collect data at 80hz and were positioned on the dominant wrist, hip and ankle. Participants performed one of two activity routines (7 activities each, 5 min/activity) including sedentary (SED), locomotion (LOC), household (HOU), and recreational (REC) activities. Accelerometer data were downloaded and transformed to 1-second epoch data using the Actilife 5 software. For each monitor, the 10th, 25th, 50th, 75th, and 90th percentiles of the vector magnitude counts corresponding to each minute of activity were calculated. These features along with the corresponding activity type label were used to train seven RF models (hip, wrist, ankle, hip + wrist, hip + ankle, wrist + ankle, and hip + wrist + ankle) for prediction of SED, LOC, HOU, and REC activity type. A leave-one-out method was used to test the accuracy of each model. RESULTS: Overall accuracy of the RF models in detecting activity type ranged from 82% to 88% using single monitor data, and from 92% to 95% when combining data from two or three monitors. The RF model with the greatest accuracy (hip + wrist + ankle) correctly classified SED, LOC, HOU and REC activities 94%, 99%, 94%, and 91% of the time, respectively. The confusion matrix for this RF model is shown in the table below.

<table>
<thead>
<tr>
<th>Actual Activity</th>
<th>Locomotion</th>
<th>Sedentary</th>
<th>Household</th>
<th>Recreational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locomotion</td>
<td>283</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Sedentary</td>
<td>0</td>
<td>137</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Household</td>
<td>1</td>
<td>13</td>
<td>412</td>
<td>11</td>
</tr>
<tr>
<td>Recreational</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>133</td>
</tr>
</tbody>
</table>

CONCLUSION: The RF models in this study accurately predicted activity type from a single or multiple accelerometers. Using machine learning models such as the RF method to detect activity type in free-living older adults may be useful for identifying mobility limitations. Funded in part by NIH R01 CA121005
INTRODUCTION: Accelerometers provide objective measurements of human activity and have been used extensively in health studies. In many of these studies, analysis was done not based on the raw data, but on summarized metrics like “activity counts”, which are the result of proprietary pre-processing software. Such metrics do not have a clear interpretation and are not comparable between devices or even batches of the same device. Thus, there is a clear and urgent need to introduce data normalization and signal extraction approaches that are transparent and meaningful. PURPOSE: The goal of this study was to introduce a transparent and explicit normalization procedure of raw accelerometry data and associated visualization tools. We also propose a series of novel metrics for transforming the large amount of information gathered by accelerometers into simple, meaningful, consistent and reproducible measurements.

METHODS: The tri-axial raw accelerometry data were first processed and each interval of one second was assigned a label, either “active” or “sedentary”. Based on the raw data and the label, 7 metrics were proposed: Wake Time, Time Active, Time Active Mean, Time Active Variability, Cumulative Relative Time Active, Activity Intensity, Activity Intensity Mean, Activity Intensity Variability and Cumulated Relative Activity Intensity. The association between some of these metrics and the subjects’ demographic predictors were studied, using the data from the Baltimore Memory Study (34 subjects, each with 3-5 days of observation). RESULTS: Self Reviewed Health, Quality of Life, Age, and Divorced were found to be significant predictors of both the mean and variability of Time Active and Activity Intensity. Gender was also a statistically significant predictor of those metrics except Activity Intensity Mean. CONCLUSION: The metrics proposed are valid, transparent and reproducible. They are generated following a clear and interpretable approach. The regression analysis demonstrates the validity of the metrics. Supported by NIBIB R01EB012547, NINDS R01NS060910
10:00 – 10:15

**Inferred Time In Bed Independently Predicts Levels Of Daytime Activity And Sedentary Behavior**

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**PURPOSE:** Increased all-cause mortality has been consistently associated with longer (8-10 hours+) self-reported sleep duration. The possibility that longer sleep may impact survival through inactive lifestyles was proposed by Morgan (2007), and subsequently tested by Hartescu et al (2012) who concluded that, independent of health status, longer sleep duration, and the inevitably longer periods of time spent in bed, could represent inactivity and/or sedentary behavior. It may be possible to infer Time in Bed (TIB: i.e. the time spent in bed irrespective of time spent asleep) from the periods excluded from daytime data collection in instrumental surveys of physical activity. The present analyses explore this possibility and address the question: is inferred TIB predictive of daytime activity/sedentary behavior levels?

**METHODS:** Profiles of health and physical activity were obtained from a random community sample of 1917 adults aged 25+ assessed for the 2008 Health Survey for England. Sedentary time and medium-vigorous physical activity (both in minutes/day) were calculated from accelerometer data over a 7-day period. The 1 minute epoch Actigraph GT1M accelerometer data was analysed using KineSoft version 3.3.75. Only those who had valid accelerometry data for at least 1 day (i.e., at least 10 hours of wear) were included. Time in Bed (TIB) was inferred from accelerometer “non-wear” periods (devices were removed at bedtime, and replaced at waking time). To assess the strength of associations between sleep and daytime variables separate regression models were fitted with sedentary time (Model 1) and moderate-vigorous activity (Model 2) as dependent variables. In both models, TIB, age, sex, BMI, health status, and mental health were entered as covariates.

**RESULTS:** The modal inferred TIB duration was 600 minutes. In the adjusted regression models, longer inferred TIB duration was significantly associated with lower levels of moderate-vigorous physical activity (r² =0.17, F(6, 1910) = 66.66, p<0.01), but also with significantly lower levels of daytime sedentary behavior (r² =0.13, F(6, 1910) = 49.08, p<0.01).

**CONCLUSION:** While the explained variance is modest, longer TIB emerged as a significant predictor of both physical activity and sedentary behavior. The directionality of these relationships, however, indicates that lower PA, rather than higher levels of sedentary behavior may be contributing to TIB-mortality relationships, supporting the use of this proxy measure as an analogue of TIB. Confirmation of these findings will be required, but the consistency of the present findings supports the use of non-wear or “non-recording” time as a proxy for time spent in bed.
10:15 – 10:30

**Machine Learning To Predict Energy Expenditure And Type Of Physical Activity From Accelerometer And Heart Rate Data**

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Email: kkatellis@gmail.com

**PURPOSE:** Wrist accelerometers are being used in population level surveillance (i.e. NHANES) of physical activity (PA) but more research is needed to evaluate the validity of a wrist-worn device for predicting PA. In this study we compare accelerometers worn on the wrist and each hip for predicting PA type and energy expenditure (EE) using machine learning algorithms. We also investigate the added value of including heart rate (HR) data in making predictions.

**METHODS:** Forty adults (21 women, 19 men; mean age = 35.8 ±12.1 yrs; BMI = 24.8 ± 2.9) performed 8 locomotion and household activities for 6 minutes in a lab setting. Participants wore three ActiGraph GT3X+ accelerometers (left hip, right hip, non-dominant wrist), a HR monitor (Polar RS400), and a portable indirect calorimeter (COSMED K4b2). METs were computed for each minute of ventilatory data and 154 features were extracted from each minute of accelerometer data. HR (beats per minute) was used as an additional feature. We developed two different predictive models: a random forest classifier to predict activity type from these features and a random forest of regression trees to estimate EE. Predictions were evaluated using leave-one-user-out cross-validation.

**RESULTS:** For predicting four activity types (household, stairs, walking, running), the hip accelerometer obtained 88.9% accuracy while the wrist accelerometer obtained 82.0% accuracy. Combining data from multiple accelerometers or including HR did not significantly improve these results. In predicting all 8 activities (laundry, window washing, dusting, dishes, sweeping, stairs, walking, running), the (left) hip and wrist accelerometers alone obtained 69.0% and 74.2% accuracy, respectively. Combining hip and wrist data led to 80.0% accuracy, but adding HR did not significantly improve results. Predicting METs using the (left) hip or wrist devices alone obtained root mean square errors (rMSE) of 1.138 and 1.249, respectively. Including HR data and multiple accelerometers improved MET estimation (rMSE = 1.061 with combined wrist, left hip and HR). There was no significant bias.

**CONCLUSIONS:** Results demonstrate the validity of random classification and regression forests for activity type and MET prediction using accelerometers. The wrist accelerometer was more useful in predicting activities with significant arm movement (e.g., household activities), while the hip accelerometer was superior for predicting locomotion and estimating EE. Results also demonstrate that HR data does not significantly improve activity classification but does improve MET estimation.
INTRODUCTION: Evidence suggests that sedentary behaviour (sitting) is detrimental for health and this association may be independent of physical activity levels. Most studies however, have focused on TV viewing with little consideration for the other ways in which sitting is accumulated such as during leisure, work or transportation. PURPOSE: The purpose of this study was to explore time spent sitting in different domains and their association with cardio-metabolic health. METHODS: Baseline data from the Sedentary Time and Diabetes (STAND) randomised controlled trial were analysed. Overweight and obese adults (N = 149, 67% female, mean age 32.8 ± 5.7 years, mean BMI 34.6 ± 5.0kg/m2) completed a questionnaire assessing time spent sitting during five domains (travel, work, TV, computer and leisure). Fasting plasma glucose, 2-h plasma glucose (measured using an oral glucose tolerance test), waist circumference, body fat percentage, blood pressure, triglycerides, total cholesterol and high-density-lipoprotein (HDL) cholesterol were measured. Forced entry linear regression models examined the associations of sitting time (in five different domains) and metabolic risk variables. RESULTS: Participants spent 81.7 (± 91.6) minutes sitting during travel, 203.4 (± 149.4) minutes sitting at work, 183.5 (± 96.4) minutes sitting watching TV, 101.1 (±86.7) minutes sitting using a computer at home and 110.6 (± 88.1) minutes sitting for leisure (not including TV). After adjustment for confounders (age, gender, ethnicity, index of multiple deprivation and moderate-to-vigorous physical activity) time spent sitting watching TV was positively associated with measures of adiposity (body fat percentage (β =0.15, p = 0.024) and BMI (β = 0.24, p = 0.007)), time spent sitting during work and leisure were positively associated with waist circumference (β = 0.26, p = 0.036; β = 0.24, p = 0.006). CONCLUSIONS: Using a domain specific sitting questionnaire reveals relationships between certain domains of sitting and measures of adiposity (body fat percentage, BMI and waist circumference) but no associations with other measures of cardio-metabolic health. These results support the potential benefit of assessing multiple domains of sedentary time.

Supported by MRC project 91409
INTRODUCTION: Time spent in sedentary behavior (SB) has deleterious effects on health. As a result, there is a strong scientific need to evaluate methods to assess SB. PURPOSE: To determine responsiveness of two motion sensors to detect change in free-living, occupational SB during an intervention to decrease sitting activity. METHODS: Adults who spent > 60% of their working day sitting were recruited to participate in an intervention to reduce SB at work. SB was assessed using two accelerometers, an Actigraph GTX3 (AG) worn on a belt, at the midline of the right thigh, and an activPAL (AP) affixed to the middle of the right thigh. SB was assessed during working hours for three consecutive days (baseline) and during the same three days the week following while undergoing the intervention (post). Data from both motion sensors were time-matched to allow direct comparison. SB was determined from time spent sitting/lying by AP and time below 100 cts/min, using 60-s epochs by AG. Pearson correlation coefficients were calculated to determine strength of association between the measures. Difference between AP and AG measures of SB at baseline and post were compared with paired samples t-test. Baseline-post intervention difference scores were compared using paired samples t-tests. RESULTS: Sixty-seven adults (45.3 ± 11.2y; 29.2 ± 7.7 kg/m2) completed the intervention. At baseline, participants spent approximately six of their eight working hours in sedentary activities. Time spent in SB as assessed by AG and AP were correlated (baseline: r=0.64, p<0.001; post: r=0.5, p<0.001). Measures of SB differed between AP and AG at baseline (AP 355.6 ± 11.0 min; AG 386.8 ± 8.2 min; p<0.001) and post assessment (AP 337.3 ± 10.8 min; AG 368.8 ± 7.7 min; p=0.002). Baseline-post AP difference scores (16.5 ± 6.8 min) were not significantly different than baseline-post AG difference scores (16.2 ± 5.6 min, p=0.56). CONCLUSION: Results reveal that both the AP and AG were able to assess responsiveness to change following a SB intervention to a similar degree. However, the AP and the AG significantly differed in their baseline and post assessment of time spent in SB. This work was supported by funding source 1-UL1-RR031973.
Objectively Determined Light Intensity Physical Activity Is Negatively Associated With Adiposity In Adolescent Females
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Email: kieran.dowd@ul.ie

INTRODUCTION: International guidelines have focused on the promotion of daily Moderate to Vigorous Physical Activity Time (MVPA) to reduce the incidence of inactivity related disease. No precise guidelines are provided for Light Intensity Physical Activity Time (LIPA). Previously, LIPA has been estimated using a sedentary count threshold. Simultaneous measurement of posture and ambulation enables the accurate categorisation of LIPA, allowing resultant relationship to adiposity measures to be explored. PURPOSE: To examine the relationship between Sitting/Lying Time (SLT), Standing Time (ST), LIPA (excluding ST), and MVPA with adiposity measures in a cohort of adolescent females. METHODS: A sample of 192 adolescent females (mean age: 15.7 yrs. (range: 13.1-18.7), mean BMI percentile: 62nd (1st-98th) were included in this analysis. Body Mass Index (BMI) was calculated from height and weight. Skinfold measurement from bicep, triceps, subscapular and iliac crest sites were summed (Σ Skinfolds (cm)). The activPAL™ (an inclinometer-based activity monitor) was worn for 7 days and minutes spent in SLT and ST were estimated from activPAL output based on upper thigh inclination. A validated threshold of 2997 activPAL counts/15s⁻¹ epoch was used to determine minutes of MVPA (Dowd et al., 2012; PLoS One, Vol. 7 (10), e47633). All remaining time was quantified as LIPA. Mean daily LIPA was divided into quartiles, with <4.5% and >6.4% of waking hours defining the lower and upper quartiles respectively. Linear Regression Analyses (LRA) examined associations between activity variables and adiposity, adjusting for age and MVPA. Odds ratios of being overweight/obese (BMI ≥85th percentile) or in the upper quartile of Σ Skinfolds (>81.5 cm) were calculated using logistic regression, adjusting for age and MVPA. RESULTS: Participants spent 9.7 (± 1.1) hrs. in SLT (66.2%), 3.3 (± 0.8) hrs. in ST (22.8%), 0.8 (± 0.2) hrs. in LIPA (5.6%) and 0.9 (± 0.3) hrs. in MVPA (6.1%). Partial correlations were found between LIPA and both BMI (r=-0.25: p<0.01) and Σ Skinfolds (r=-0.25: p<0.01), while LRA indicated that LIPA significantly predicted BMI (Beta = -0.25, p<0.01) and Σ skinfolds (Beta = -0.25, p<0.01). Compared to participants in the highest LIPA quartile, participants in the lowest quartile had greater odds of being overweight/obese (odds ratio [OR] 5.13, 95% CI 1.53-17.44) and of having higher Σ Skinfolds (OR 3.75, 95% CI 1.22-11.53). CONCLUSION: A relationship exists between LIPA and measures of adiposity in this sample, even after controlling for age and MVPA. Increasing LIPA by reducing SLT may represent a useful target for interventions to improve adiposity markers.
INTRODUCTION: Too much time spent sitting has been identified as a public health risk, independent of a lack of physical activity. While objective measures of sitting time and sedentary behaviour are becoming more widely used, self reported measures of sitting time are still the most pragmatic and frequently used solution for population surveillance. The International Physical Activity Questionnaire (IPAQ) is a widely used self reported measure, and includes items assessing sitting time. These items were deemed approximately as valid and reliable as sitting time measured objectively with an Actigraph. However, it is accepted that using the Actigraph as a criterion measure does not provide a true measure of sitting, and it has recently been recognised that inclinometers such as activPAL offer a more valid and accurate objective measure of sitting time. **PURPOSE:** To compare the accuracy of the IPAQ sitting time item against a robust objective measure of sitting time (activPAL). **METHODS:** A convenience sample of volunteers (N=80; 25 to 62 years old) were recruited from the general population of Glasgow. They wore an activPAL activity monitor continuously for 7 days. At the end of this period the participants completed the IPAQ sitting items detailing the time spent in sitting during week and weekend days. The activPAL data were processed to identify sitting periods and total sitting time over the same periods for each individual. IPAQ and activPAL data were compared using intraclass correlation coefficients (ICC), Pearson correlation and Bland Altman analysis for sitting time over the total week, week days and weekend periods. **RESULTS:** Correlation between IPAQ and the criterion objective measure is very low (total week ICC=0.11, week days ICC=0.16, weekend ICC=0.28) and no statistically significant linear correlations were found. The Bland Altman revealed that sitting time was consistently underestimated by IPAQ. This error was systematic across the range of objectively measured sitting time for the total week (mean = 3.39 h/day, CI [0.56 6.21]) and for the weekend (mean = 4.64 h/day, CI [1.24 8.03]). For week days the mean difference was 3.43 h/day (CI [0.62 6.25]), but showed a trend, inversely proportional to the amount of sitting suggesting that the error is relative to the total amount of time spent sitting. **CONCLUSION:** The sitting items of IPAQ are a poor measure of sitting time in terms of accuracy. They underestimated true sitting time, which suggests that population surveys based on IPAQ might also be underestimating the prevalence of sitting time. However due to the systematic nature of the error it might be possible to develop corrections for the IPAQ items.
Validity of Automated Estimation of Worn Waking Time for ActivPAL Data
Elisabeth AH Winkler¹, Genevieve N. Healy¹, Sebastien FM Chastin².¹The University of Queensland, Herston, Australia.²Glasgow Caledonian University, Glasgow, United Kingdom. Email: e.winkler@sph.uq.edu.au

INTRODUCTION: Automated estimation is a low-burden method to estimate accelerometer non-wear that is essential for large-scale studies. However, no published research to date demonstrates the validity of automated estimation algorithms for activPAL data. Removing non-wear and sleep from activPAL data has required the use of self-report data or untested approaches, such as assuming the longest bout of sitting/lying each day is sleep and assuming periods of at least 60 minutes of zero acceleration are non-wear. PURPOSE: Using baseline data from a workplace sitting intervention, we compared several automated estimation algorithms with self-reported worn waking time. METHODS: Office workers (n=43) were asked to wear activPALS continuously for seven days and report their sleeping and removal times in a diary. For the referent assessment method, each bout from the activPAL events files was classified as awake (or asleep) and removed (or worn) depending on whether or not most (i.e., >=50%) of the bout fell into those classifications according to self-report. Six different automated estimations were implemented and compared with the referent assessment method: at least 60, 90, 120, 240 and 360 minutes of continuous sitting/lying and at least 60 minutes of continuous zero acceleration. Bland-Altman analysis assessed agreement in daily worn waking time and Kappa assessed agreement of the wear classification of each bout. As misclassification is most problematic for the longest bouts, Kappa was assessed with weighting for bout duration (in minutes). RESULTS: Prolonged zero acceleration classified all time as worn waking time. The smallest mean differences [95% Limits of Agreement] in daily worn waking time against the referent method were provided by 60 and 90 minutes of continuous sitting/lying (-31 [441, 379] and 41 [-350, 433] minutes, respectively). The best agreement in wear classification was provided by 90 and 120 minutes of continuous sitting/lying (Kappa [Standard Error] = 0.75 [0.03] and 0.75 [0.04], respectively). CONCLUSION: Automated estimation of worn waking time based on prolonged sitting/lying may be useful for large-scale studies employing activPALS, with 90 minutes being the most supported minimum non-wear period. The level of accuracy is acceptable and comparable to automated estimation with other accelerometer data. Wider validation in more general populations is needed. Grant funding: This study was funded by an NHMRC project grant [#1002706], with additional financial support from the Victorian Health Promotion Foundation.
Assessment Of Sedentary Behaviours, Activity And Sleep With A Wrist-worn Accelerometer; Introducing The Sedentary Sphere

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Email: alex.rowlands@unisa.edu.au

BACKGROUND: There is a need for an unobtrusive, objective method that enables the assessment of sedentary behaviour, physical activity and sleep concurrently in free-living individuals. PURPOSE: The aims of the present study were: a) to determine whether a wrist worn accelerometer can provide valid measures of sedentary time, activity and sleep and b) to explore a novel method for the analysis, identification and visual presentation of sedentary behaviours, the Sedentary Sphere. METHODS: Thirteen adults (age (mean±SD) 34.5±13.2 y) wore a GENEActiv on their wrist and an ActivPAL on their thigh for 24 h. The next day they completed the Multimedia Activity Recall for Children & Adults (MARCA), a computerised use of time instrument. Posture was determined from the GENEActiv and ActivPAL data. Time classified as sleep, sedentary, and moderate-to-vigorous activity (MVPA) was determined from the GENEActiv and the MARCA. GENEActiv data were plotted on the Sedentary Sphere. RESULTS: Sitting time, determined by the GENEActiv (995±128 min), correlated positively with and did not differ significantly from ActivPAL sitting time (1015±99 min), (r = 0.85, p < 0.001). Intra-individual classification agreement across 15 s epochs was 83.9±7.6% (mean kappa = 0.63 ± 0.29). Time classified as sleep and MVPA by the GENEActiv correlated with the corresponding time reported in the MARCA (r=0.71, r=0.70, p < 0.05, respectively). Intra-individual sleep classification agreement between the GENEActiv and MARCA for 5 min periods was 89.8±5.5% (mean kappa = 0.77±0.42). GENEActiv acceleration data were plotted in 3 dimensional space. When sedentary, gravity provided the primary signal allowing wrist elevation (latitude) and rotation (longitude) to be determined. Periods of consecutive points formed distinct clusters which could be differentiated by their position and distribution. These clusters corresponded to specific behaviours with the sedentary behaviours distributed on the surface of a sphere of radius 1g determined by gravity within the signal. Where behaviours included significant levels of acceleration (i.e. they were active and non-sedentary) the clusters were differentiated by points that departed substantially from the surface of the sphere. CONCLUSION: The wrist-worn GENEActiv is an unobtrusive device that can simultaneously assess physical activity, sedentary behaviour and sleep. Concurrent validity with accepted measures of each outcome is good. The Sedentary Sphere can be used to classify sedentary behaviours; location on the surface of the sphere is indicative of posture and movement away from the surface represents the amount of energy of a movement.
Contemporaneous Assessment Of Physical Activity, Sedentary Behavior And Sleep Using An Actigraph GT3X+ Accelerometer

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INTRODUCTION: Physical activity (PA), sedentary behavior (SB) and sleep form the behavioral tripartite of energy expenditure and appear inter- and independently related to cardiometabolic disease and cancer. The ability to collect valid data on all three behaviors contemporaneously using one type of accelerometer is important because it may improve our understanding of behavioral inter-relationships while lowering research costs and participant burden. PURPOSE: (i) Examine the feasibility of using an ActiGraph GT3X+ accelerometer to measure PA, SB and sleep during 7 days and 7 nights of continuous monitoring; (ii) measure the day-to-day variability in PA, SB, and sleep habits, and (iii) examine associations between PA, SB and sleep. METHODS: Twenty three women (mean age = 54.7 ±15.5 yrs; BMI = 31.8 ±3.4) wore an ActiGraph GT3X+ accelerometer on their hip for 7 consecutive days during waking hours, and the same device on their non-dominant wrist 24 hr/day for 7 days. PA and SB data were scored using validated cut-points (SB = <100 counts per min [CPM]; moderate intensity PA = 1952-5724 CPM; vigorous PA = >5724 CPM. Non wear time was defined as 90 consecutive minutes of zero count data. Sleep data were scored using the Cole-Kripke algorithm in ActiLife v6.5.1. Self-reports of bedtime and out-of-bed time were used to establish the sleep analysis window for each actigraphy file. RESULTS: Compliance to wearing the hip-mounted device for the full monitoring period was 83% (mean wear time = 5.8±1.3 days, 13.4±1.8 hr/day). Compliance to wearing the wrist-device was 102% (7.13 ±0.87 nights). Across all participants, 133 days of matched PA, SB and sleep data were collected. The within-person daily stability (intraclass correlation, R) of SB and moderate-to-vigorous PA was 0.78 and 0.86, respectively. The nightly stability of sleep parameters were R = 0.93 (Total Sleep Time), 0.89 (Sleep Efficiency), 0.13 (Sleep Latency), and 0.84 (Wakefulness After Sleep Onset). Daily PA and SB were not significantly associated with subsequent nightly sleep parameters (range, r = -0.2 to 0.1), although associations were stronger (range , r = -0.45 to 0.33) when weekly averages were used. CONCLUSION: It is feasible to collect PA, SB and sleep data contemporaneously using an ActiGraph GT3X+ accelerometer. A 5-7 day monitoring period was sufficient to yield stable estimates of all measured variables, except sleep latency. Future research should attempt to examine associations between PA, SB and sleep in a larger sample and validate the use of the GT3X+ for sleep assessment using polysomnography. This study was supported by funding from the NIH/National Cancer Institute (TREC 1U54 CA155435-01)
PURPOSE: The 2010 physical activity (PA) guidelines for older adults in the UK include a target of 150 minutes of moderate or vigorous PA (MVPA)/week and recommend minimizing time spent being sedentary in extended periods. There are few large studies of objectively measured PA in the elderly which can estimate the prevalence and predictors of adherence to PA guidelines which are likely to provide health benefits. We therefore investigate prevalence of adherence to MVPA guidelines using two thresholds for PA bouts and describe levels of SB, among older men. METHODS: In 2010-2012, 3292 British men aged 70-93 years participating in an on-going population-based cohort study recruited from primary care centres in 24 British towns were invited (by post) to wear an Actigraph GT3X accelerometer over the hip for 7 days and complete questionnaires. Uniaxial data were analysed in 60s epochs. Bouts of >120 minutes of continuous zeros with no interruptions were excluded. >=3 valid days (of >=600 minutes wear time) were required for inclusion in analyses. Cut point thresholds were <100 (sedentary behavior), 100-1951 (light) and >=1952cpm (MVPA), in bouts of 1 minute (MVPA-1) or bouts of >=10 minutes (MVPA-10+). Logistic regression models were used to model MVPA and adjusted for age, region, day order, month and accelerometer wear time. RESULTS: 1674 (51%) men participated, mean age 78 years. 7% men did MVPA-10+, and 27% did MVPA-1. Achieving MVPA-10+ was associated with younger age, having no mobility limitations (OR 8.4, 95%CI 2.05, 34.37) and no chronic diseases (OR 2.06, 95%CI 1.38, 3.06), not being depressed (OR 4.87, 95%CI 2.10,11.25) or fearful of falling (OR 3.45, 95%CI 1.48, 8.63), having higher exercise self-efficacy (OR 2.72 95%CI 2.07, 3.56) and outcomes expectations (OR 1.88 95%CI 1.53, 2.32), leaving the house >=5 days/week (OR 3.62 95%CI 1.45,9.05), living near green spaces (OR 1.67 95%CI 1.13,2.47) and walking a dog (OR 2.28 (95%CI 1.39, 3.73). In models adjusted for all covariates, exercise self-efficacy and dog walking remained significant and little changed. The same variables were associated with achieving MVPA-1. Total daily minutes of MVPA and SB were weakly inversely correlated (r=-0.20). Mean total SB was 658 (SD 112) mins/day, of which 156 (SD 125) were spent in bouts of 60 minutes or more. CONCLUSIONS: Adherence to MVPA guidelines is low in older men (varying 7-27% depending on assumptions) and burden of SB is high, leaving room for substantial potential health gain. Poor mental and physical health were important barriers and important modifiable facilitators were dog walking and high levels of exercise self-efficacy.

Funding: NIHR Post Doctoral Fellowship
INTRODUCTION: Physical activity is known to prevent cardiovascular disease (CVD). However, the relative importance of accumulating physical activity in sustained bouts versus shorter bouts in terms of CVD risk is yet to be determined. Purpose: The aim of this study was to investigate the relationship between moderate-to-vigorous physical activity (MVPA), measured in bouts ≥10 minutes and <10 minutes, and CVD risk factors in a nationally representative sample of adults. METHODS: A sub-sample of adults (aged ≥16 years) from the 2008 Health Survey for England with valid accelerometry data for at least 1 day (i.e. ≥ 10 hours of wear time) were included in the study (N = 2353). The one minute epoch ActiGraph GT1M accelerometer data was analysed using KineSoft version 3.3.75. Total MVPA, MVPA accumulated in bouts ≥10 minutes (MVPA10+), and MVPA accumulated in bouts <10 minutes (MVPA<10) were calculated (Troiano et al. 2008). MVPA exposures were related to individual CVD risk factors, including measures of adiposity (BMI & waist circumference), blood cholesterol (Total and HDL), systolic and diastolic blood pressure, and HbA1c, using linear regression (controlling for age, sex, and accelerometer wear time). All statistical analyses were conducted using SPSS version 20. RESULTS: The mean age of the participants was 51.6 years, 55% female, with a mean BMI of 27.5 kg/m2. Total MVPA was significantly associated with lower waist circumference and higher high-density lipoprotein (HDL) levels, (P<0.0001). None of the other CVD risk factors were significant. MVPA10+ also showed statistically significant associations with these two CVD risk factors (P <0.001). However, MVPA<10 was not significant for HDL and the significance level for waist circumference dropped to (P<0.003). CONCLUSION: Our cross-sectional observations on a large nationally representative sample confirm a positive association of MVPA with a healthier CVD risk factor profile. However, these data suggest that health benefits of MVPA in terms of HDL cholesterol, are only realized when sustained bouts are accumulated. That said, for waist circumference these data indicate that accruing MVPA in bouts <10 minutes may favourably influence CVD risk. Additional investigations are warranted to confirm these findings.
Intra-Day Physical Activity Patterns in Young and Older Adults
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INTRODUCTION: While many studies report lower daily physical activity (PA) in older compared with young adults, few have focused on how PA patterns may vary over the course of a day. Our working hypothesis is that older adults who report fatigue may adjust their behavior such that they accumulate relatively more of their PA early in the day. PURPOSE: Our purpose was to develop and test a method to quantify intra-day PA behavior, based on accelerometer data, in young and older adults. We also explored the association between PA and symptomatic fatigue. METHODS: Accelerometer data were collected from 22 Young (22.9 ± 0.5 yr, mean ± SE; 12 Male, 10 Female) and 21 healthy Older (73.0 ± 1.3; 9M, 12F) adults. Young and older groups were matched for total daily PA. An accelerometer (Actigraph GT1M, Pensacola, FL) was worn at the hip during waking hours for 10 days; activity was recorded in 60s epochs. A survival curve analysis (Mathworks, Natick, MA) was used to quantify the timing (relative to wear time) of PA use (relative to total daily counts) over the course of each day. The relative time remaining in the day when PA had accumulated to 25%, 50%, and 75% of daily total (Time_{PA25}, Time_{PA50}, and Time_{PA75}, respectively) was calculated. In a subset of 12 Older adults, symptomatic fatigue was evaluated using the Multidimensional Fatigue Inventory (MFI; Smets et al, 1995). RESULTS: Total PA did not differ between groups, nor did Time_{PA25}. However, Time_{PA50} and Time_{PA75} were higher in Older, indicating that they completed a greater percentage of their daily PA earlier in the day than Young. In the older subset, MFI was correlated with PA_{50} and PA_{75} (r≥0.78, p<0.01), such that those with greater fatigue completed a higher percentage of their PA earlier in the day.

<table>
<thead>
<tr>
<th></th>
<th>Total Counts (cts·day(^{-1000}))</th>
<th>Time_{PA25} (% day remaining)</th>
<th>Time_{PA50} (% day remaining)</th>
<th>Time_{PA75} (% day remaining)</th>
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<tbody>
<tr>
<td>Young</td>
<td>213 ± 14</td>
<td>74.7 ± 1.3</td>
<td>55.4 ± 1.3</td>
<td>35.3 ± 1.3</td>
</tr>
<tr>
<td>Older</td>
<td>227 ± 22</td>
<td>76.9 ± 1.5</td>
<td>61.0 ± 1.9</td>
<td>42.3 ± 1.9</td>
</tr>
<tr>
<td>p-value</td>
<td>0.61</td>
<td>0.27</td>
<td>0.02</td>
<td>&lt;0.01</td>
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CONCLUSIONS: These results illustrate the utility of this new approach, and suggest that older adults of comparable total PA accumulate their PA earlier in the day than do young adults. We also provide preliminary evidence that this shift may be associated with fatigue in older adults, supporting the possibility that these individuals may tire early and become sedentary during the latter part of their day.
Support: NIH R01 AG21094
Accessing the Accuracy of Accelerometry to Measure Gait Speed
Klaus-Hendrik Wolf¹, Michael Marschollek², Andreas Hornberger¹, Matthias Gietzelt¹. ¹TU Braunschweig, Braunschweig, Germany. ²Hannover Medical School, Hannover, Germany.

PURPOSE: Gait speed is a predictor of several health-related conditions, e.g. dementia and it is even a measurement of rehabilitation processes [1]. In theory, it is possible to measure gait speed using accelerometry. METHODS: We conducted a study to measure gait speed with a single waist-mounted accelerometer. The study took place during a public science presentation show in order to reach a broad spectrum of participants [2]. The participants were asked to walk 20 m at self-selected speed. They wore an accelerometer, which was cased in a belt bucket. Simple statistical parameters were computed on the Euclidian norm of the tri-axial accelerometer signal. The Euclidian norm was chosen, because this parameter is orientation-invariant. A quadratic regression analysis was used to compute gait speed from the data. RESULTS: A heterogeneous sample of 111 healthy subjects was analyzed (50 female). The subjects were 49.1 ± 23.9 years old (range 7 to 86), their body weight was 68.1 ± 17.6 kg (range 20 to 104), and their height was 168.1 ± 14.2 cm (range 115 to 190). Age did not correlate with walking duration, dur, (r=0.23) or the measured gait speed (r=−0.24). The regression analysis eliminated all parameters except for dur and variance: speed = 0.00253•dur² - 0.14866•dur - 0.02901•dur•var + 0.08308•var² + 0.85146•var + 2.94126A 10 fold cross-validation showed a coefficient of correlation of 0.9887 and a mean absolute error of 0.024. Figure 1 shows the result of applying the formula to the sample. CONCLUSION: We showed that gait speed can be computed from orientation-independent accelerometeric parameters with high accuracy. It remains to be shown that the formula is also able to reliably estimate gait speed in other settings.

INTRODUCTION: About one third of home-dwelling elderly fall each year. Falling results in deaths, physical injuries and affects the quality of life and the ability to live independently. Automatic fall detectors are one method of improving the security of elderly. However, in most cases, fall detectors are designed and tested with data collected from experimental falls in younger people. PURPOSE: The aim of this study was to evaluate long-term sensitivity and false alarm rate of a fall detector in real-life use among older people. METHODS: Sixteen older people (mean age 88±5 years) living in elderly care units were recruited to wear a prototype of an automatic fall detector [1]. The device was designed to collect acceleration data. The implemented fall detection algorithm detected impact from an acceleration sum vector and end posture based on the vertical axis acceleration. In addition, the sensor continuously collected activity data in order to evaluate the usage of the sensor. The sensor was attached on the waist with an elastic belt. Real-life falls were identified based on the reporting by the care personnel. The number of fall alarms was collected from the database based on the fall label generated by the system. RESULTS: Altogether 12 382 hours from 975 days of real life were monitored with the sensor. Most of the test subjects wore the sensor during waking hours (average 13.1±1 hours per day). The false alarm rate varied from 0.000 to 0.178 alarms per hour, with an average value of 0.049±0.004 alarms per hour, corresponding to 1.2 false alarms over a 24-hour time period. During the test period the sensor system was reported to be used during 15 fall events. The acceleration data of real-life falls were collected from 13 of those and 12 of them were detected as falls by the fall detection algorithm. This results in a fall detection sensitivity of 80%. In two fall cases the criterion for data collection triggering was not fulfilled and in one case the acceleration data was collected but not detected as a fall because of the non horizontal end posture. CONCLUSION: In this study, real-life sensitivity and false alarm rate of an accelerometer based fall detector among old persons living in elderly care units were analyzed. These data suggest that automatic accelerometric fall detection systems might offer a tool for improving home safety among older people. In future, more advanced algorithms to further reduce the false alarm rate would increase the applicability of the system. Supported by: the European Regional Development Fund of the European Union, Finnish Funding Agency for Technology and Innovations, and the Academy of Finland. [1] Kangas et al. Gait Posture 2012;35(3):500-5
Assessing Feasibility of Using Wearable Foot Pressure Sensor After Injury
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INTRODUCTION: The smart house with many sensors and broadband-ubiquitous home network will support new services, especially for the elderly. Simple sensors will be the key to capturing the data needed, including vital medical information. This will stimulate new infrastructures or services in Home Healthcare, or e-Health. PURPOSE: In order to clarify how sensor-based systems can assess the rehabilitation status of people with leg injuries, we conducted experiments on using a wearable foot pressure sensor to capture foot pressure while walking. This paper details the results of an extended experimental period, about 1.5 year, that differ from the initial results presented [1]. METHODS: A healthy female (45 y) injured her left leg and fell down while playing tennis about 2 years before. She had pain on the left side of the left knee; X-rays indicated no bone was broken. An MRI diagnosis indicated ACL damage, bone bruise just under the left knee, no damage of collateral ligament, and stretched status of PCL. An MD determined that recovery would take 6 months (mo.). The 16 mo. period after the injury included; i) Clinical ordinary treatment by the MD, ii) Rehabilitation (stretching and muscle exercises) as per the MD’s instruction, iii) Daily physical status report, and iv) Weekly foot pressure measurements while walking on a wooden flat floor using a wearable sensor (Pedar system [2]). The subject walked at a speed comfortable to her, i.e. no pain, about 2 km/h. After the warm-up for about 2 min, she first walked 5.5 m in a straight line, stopped for 10 sec, and then walked back. This cycle was repeated 4 times in total. Peak pressure at the terminal stance in a cycle, average time period and the COP were measured and analyzed. Scores for pain, fatigue intensity, and walking ability taken from the subject daily report were also analyzed. RESULTS: Peak pressure and average time period for 3 cycles indicated significant improvement in walking ability over the initial 2 mo., and a slight further improvement in the next 2 mo. They remained unchanged values thereafter. Fatigue intensity and walking ability mirrored these trends. However, pain intensity was different in that the pain steadily reduced in the first 4 mo., reduced little by little until the virtually normal condition was reached after 12 mo. The MD declared her recovered at 16 mo. after the injury. CONCLUSION: Our experiment clarified that rehabilitation status can be partially discerned from sensor data. Such information will help to motivate the subject to continue with rehabilitation even at home. Further COP analysis in detail will help detailed assessment.
REFERENCES:
Normal Ranges for Novel Measures for Balance Quality in Healthy Individuals and Patients based on Mobile Accelerometry
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Email: cristina.soaz@tum.de

INTRODUCTION: Poor balance control is an important factor to predict risk of falling. The clinical screening methods to assess balance (e.g. the recorded time) are affected by floor and ceiling effects. Recently, accelerometers have been presented as a portable and feasible alternative with strong correlations to force plate signals. However, standards and information about reference values are still missing. PURPOSE: The purpose was to generate standardized balance acceleration data, compare normal ranges and gain knowledge about human postural control behaviour in patients with Multiple Sclerosis (MS), osteoporosis and healthy individuals.

METHODS: 98 females with osteoporosis (68.8 ± 4.9 yrs), 50 healthy individuals (29.3 ± 9.7 yrs) and 28 MS patients (49.1 ± 8.5 yrs, EDSS 4-6.5) were recorded with a triaxial accelerometer when performing the following tests: Romberg (T1), Semi-tandem (T2), Tandem (T3) and One Leg Stand Test (T4). With eyes open/closed (EO/EC). Data was preprocessed and parameters extracted. The key outcome is the area covered by the best matching ellipse that includes 95% of the acceleration points in the horizontal plane.

RESULTS: Formally significant differences were found for the 3 groups for the T1EO and T3EO tests (p<0.0001; Kruskal-Wall test). Differences were not statistically significant for healthy vs. osteoporotic patients (p=0.08805 for T1EO and p=0.1057 for T3EO; Wilcoxon rank sum test). Area of ellipse [BU] (1BU=0.096 m²/s⁴)

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<th>Healthy</th>
<th>Osteoporosis</th>
<th>MS</th>
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<tbody>
<tr>
<td>T1EO</td>
<td>0.54 +/-</td>
<td>0.42 +/-</td>
<td>2.15 +/-</td>
</tr>
<tr>
<td>T2EO</td>
<td>0.33 +/-</td>
<td>0.25 +/-</td>
<td>1.36 +/-</td>
</tr>
<tr>
<td>T3EO</td>
<td>0.70 +/-</td>
<td>1.00 +/-</td>
<td>5.53 +/-</td>
</tr>
<tr>
<td>T4EO</td>
<td>0.43 +/-</td>
<td>0.58 +/-</td>
<td>4.20 +/-</td>
</tr>
<tr>
<td>T1EC</td>
<td>0.98 +/-</td>
<td>1.51 +/-</td>
<td>16.00 +/-</td>
</tr>
<tr>
<td>T3EC</td>
<td>0.55 +/-</td>
<td>0.90 +/-</td>
<td>13.14 +/-</td>
</tr>
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</table>

CONCLUSIONS: The results show a clear difference between the balance ability of healthy individuals and MS patients with moderate/high levels of disability, that can at best be partially explained by the difference in age. Test difficulty is much higher when eyes are closed (about a factor of 2). There are also differences between healthy individuals and patients with osteoporosis, in the range of 1.5-3, but not for the easiest test (T1EO) that has no distinctive power here. Overall the results are plausible and promising and will need to be further enhanced by more data from a wider range of patients with balance disorders and different age.
8:30 – 8:45
CSTS and MARS Models Using Accelerometry and Heart Rate Predict Energy Expenditure of Preschoolers
Nancy F. Butte1, Anne L. Adolph1, Maurice R. Puyau1, Firoz A. Vohra1, William W. Wong1, Issa F. Zakeri2. 1USDA/ARS CNRC, Baylor College of Medicine, Houston, TX. 2Drexel University, Philadelphia, PA. Email: nbutte@bcm.edu

INTRODUCTION: Preschool-aged children have higher basal metabolic rates, heart rates and metabolic costs of movement than older children. Because the relationships between accelerometer counts (AC), heart rate (HR) and energy expenditure (EE) are confounded by growth and maturation, age-specific EE prediction equations are required. Mathematical modeling of these relationships has been limited to linear regression in preschoolers, unlike older children and adults, where advanced mathematical modeling has proven powerful in the prediction of EE. PURPOSE: We validated cross-sectional time series (CSTS) and multivariate adaptive regression splines (MARS) models to predict EE in preschoolers using advanced technology (fast-response room calorimetry, doubly labeled water method, Actiheart and Actigraph accelerometers and miniaturized HR monitors). METHODS: CSTS and MARS models for the prediction of minute-by-minute EE were validated in 50 preschool-aged children, ages 3 to 5 y, against room calorimetry and DLW. Free-living total energy expenditure (TEE) was measured over a 7-d period using the DLW method simultaneously with Actiheart and Actigraph GT3X+ monitoring. CSTS and MARS models were based on subject characteristics (gender, age, weight, height), Actiheart (HR+ accelerometer counts, AC_x) or ActiGraph parameters (AC_x, AC_y, AC_z, steps, posture), and their significant 1- and 2-minute lag and lead values, and significant interactions. RESULTS: Relative to EE measured by calorimetry (mean ± SD, 1.08 ± 0.24 kcal/min), mean percent errors predicting EE were within 10% for 70% of cases with the CSTS and MARS models based on the Actiheart and Actigraph+HR. Concordance correlation coefficients (CCC) were 0.82 and 0.92 for CSTS EE models, and 0.85 and 0.88 for MARS EE models. Relative to TEE measured by DLW mean percent errors were within 10% for 68% of cases with the CSTS and MARS models using Actiheart and Actigraph+HR. CONCLUSION: CSTS and MARS models that capture the complex dynamics of EE and movement characteristic of preschool-aged children can be used for the quantitative assessment of EE.

Supported by USDA/ARS under Cooperative Agreement No. 58-6250-0-008 and National Institutes of Health (NIH) Grant number R01 DK085163
INTRODUCTION: Types and durations of activities that people engage in during their daily routine are important to consider when studying links between physical activity, sedentary behaviors, and health. Within the framework of the SVELTE project, a classification algorithm using Gaussian mixture models capable of identifying 8 postures and activities from 3-axial accelerometer and magnetometer data was developed. This tool was initially parameterized with data from activities performed in controlled conditions. PURPOSE: The purpose of this study was to test the performances of this algorithm on field data, and to compare them with those of a commercially available device. METHODS: 20 subjects equipped with 2 hips-worn 3-axial accelerometers (1 MotionPOD, MOVEA; 1 Actigraph GT3X+, ActiLife) engaged in a set of indoor and outdoor activities (e.g. sitting at a desk, walking down the streets, shopping, cycling, using public transports, etc.). Subjects were free to perform activities at their own pace. Postures and activities were noted and timed by an observer. MotionPOD data were processed with the new algorithm, resulting in the subjects’ postures being classified as lying down, slouched, sitting, standing, making few steps, walking, running, or cycling. The Actigraph’s inclinometer provided a 3-class classification (standing, sitting, or lying). Confusion matrices were used to compare the outputs of each method to the observer’s notes. Outputs from the new algorithm were considered at both the native 8-postures output and after grouping into the same 3 basic postures as the Actigraph data. RESULTS: Lying down and standing activities were better identified with the new tool than with the Actigraph (sensitivity = 99.9 vs. 90.2 %, and 97.7 vs. 91.7 %, respectively), but not sitting activities grouped altogether (57.7 vs. 73.4 %). Cycling outdoor and sitting when in a motorized vehicle proved difficult to identify for the initial lab-calibrated algorithm. Data from 10 subjects were used as a learning set to define a distinct ‘outdoor cycling’ category. The new 9-posture classification performed well on several common activities: lying down 99.9%, sitting at a desk 70.9 %, slouched 72.6%, all walks 76.8%, making few steps 51.2%, running 94.8%, and cycling on flat 80.1% (cycling sensitivity calculated only on subjects not included in the learning set). CONCLUSION: Although further improvements are required, the new tool already increases the panel of activities that can be detected and paves the way to interesting studies on lifestyle behaviors. It should also prove useful to improve energy expenditure calculations derived from motion devices.

Funding: ANR TECSAN
9:00 – 9:15

**Is Accelerometry Really Measuring Travel-related Physical Activity During The Hour Before And After School?**

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Email: afrazer@uvic.ca

**INTRODUCTION:** Physical activity (PA) from active travel to and from school is commonly inferred by windowing accelerometry data during the hrs before and after school. However, no study has validated this method against travel diaries. **PURPOSE:** To investigate the convergent validity of using the hr-window before and after school to measure travel PA (against travel diaries), and to establish if either method describes between-travel-mode differences in travel PA. **METHODS:** Forty-nine students (13.8±0.6 yrs) attending a public high school in downtown Vancouver participated in a school-based study in fall 2012. Students were instructed to wear an accelerometer (GT3X+) on the right waist for the next 7d and to complete a travel diary, indicating: travel mode and start/stop times (hh:mm) for trips to and from school on each school-day. Students providing accelerometry data and travel diaries for at least one ‘routine’ school-day (no clubs and/or early or late travel to and from school) were included for analyses (n=24, 42% girls). Accelerometry files (1s epoch) were windowed (hr before, hr after, travel to, travel from) and uniaxial counts were converted to moderate-to-vigorous PA (MVPA; Evenson et al., ‘08) using ActiLife (v. 6.4.3). **RESULTS:** MVPA during the actual trip to and from school explained 66% (p<0.01) and 49% (p=0.01) of MVPA during the hr windows before and after school, respectively. Using transit was most commonly reported for travel to (53%) and from (45%) school, followed by walking (29%, 41%) and car use (18%, 14%). There were significant between travel-group differences in MVPA during the hr before (F=11.05, p<0.01) and during the actual trip to school (F=5.82, p=0.02); by either method, walkers were most active (20.3±9 min, 11.2±6 min, respectively) compared with transit (11±1 min, 6.8±3 min) and car users (3.4±0.8 min, 0.8±0.4 min). After school, MVPA was only different between travel modes during the hr after school window (F=5.71, p=0.01), but not the actual trip from school (F=1.27, p=0.31). In the hr after school, walkers were more active (16.2±5 min) than transit (11.6±3 min) and car users (7.5±4 min). It made no difference whether MVPA was calculated based on accelerometer data from ‘routine’ days vs. any weekdays for the hr before (t=1.65, p=0.12) or after school (t=1.62, p=0.12). **CONCLUSION:** Windowing accelerometry data during the hr before and after school may be used to crudely estimate travel PA. However, those who seek a precise estimate of travel PA may wish to consider including travel diaries or Global Positioning Systems. Why PA before and after school differs by travel mode - irrespectively of travel PA - warrants exploration.
Modeling Simultaneous Heart Rate and Accelerometry to Estimate Energy Expenditure
Scott J. Strath, Nora E. Miller, Elizabeth K. Lenz, Ke Yan, Raymond Hoffmann, Ann M. Swartz.
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INTRODUCTION: There is a need to investigate methods to improve upon the accuracy and precision of physical activity energy expenditure (EE) estimations. Purpose. To compare different linear segmented models to integrate heart rate (HR) and accelerometer (ACC) data to estimate EE. METHODS: 147 adults underwent measures of anthropometrics, resting oxygen uptake (V02), and maximal V02. Each individual was then assessed for V02, HR and ACC while performing treadmill walking and running activities (1.0-4.0mph in 0.5mph increments, and 6, 7 and 8mph: duration 5 min/stage) and simulated activities of daily living (computer work, vacuuming, mopping/sweeping, carrying/moving boxes and stair climbing/walking: 7 mins each). Mean HR, ACC and METs (measured activity V02 divided by measured resting V02) from each activity was then used in linear segmented regression modeling examining different a priori HR join knots to condition the cross over between using ACC and HR to predict METs. The Jackknife approach was used to compare root mean square error (RMSE) across evaluated models to predict METs before and after controlling for gender, BMI, resting and maximal V02. RESULTS: The overall sample (age=49±17 yrs, BMI=25.8±4.5 kg/m2, resting V02=2.88±0.46 mL/kg/min, maximal V02=34.2±10.1 mL/kg/min) was categorized into the following age ranges 1) 18-39 yrs (n=48), 2) 40-64 yrs (n=65), and 3) 65+ yrs (n=34), that completed a total of 667, 853 and 414 activities, respectively. Models conditioned to join ACC and HR at an individual HR walking response at 2.5mph was deemed the most accurate. The following models were then evaluated for accuracy to predict METs across all activities: Model 1 unadjusted: If HR<HR at 2.5mph, then METs=a1+b1*ACC, if HR≥HR at 2.5mph, then METs=a2+b2*HR; Model 2 unadjusted: If HR<HR at 2.5mph, then METs=a1+b1*ACC, if HR≥HR at 2.5mph, then METs=a2+b2*HR+b3*ACC; Model 3 was the same as model 2, but adjusted for covariates. Model 3 showed the greatest accuracy in predicting METs with RMSE values 0.94 METs (18-39yrs), 0.93 METs (40-64yrs), and 0.92 METs (≥65yrs). CONCLUSION: Integrating HR and ACC using a defined HR walking response to condition an ACC and HR model offers an accurate method to estimate EE. Future studies comparing this approach to other prediction methods are warranted. This work was supported by funding source R01HL091019.
8:30 – 8:45

**Estimating Energy Expenditure Using Propulsion Power During Wheelchair Locomotion**
Scott A. Conger, Stacy N. Scott, David R. Bassett, Jr..*University of Tennessee, Knoxville, TN.*
Email: sconger@utk.edu

**INTRODUCTION:** The objective assessment of energy expenditure (EE) in individuals who use wheelchairs have yielded mixed results due to the increased EE associated with locomotion on different surfaces and different grades. The measurement of wheelchair propulsion power could improve on existing methodologies by quantifying the intensity associated with wheelchair locomotion. **PURPOSE:** To examine the relationship between hand rim propulsion power and EE during wheelchair locomotion. **METHODS:** Fourteen individuals who used manual wheelchairs were included in this study. Each participant performed five different activities for eight minutes each in a wheelchair with a PowerTap hub built into the rear wheel. The activities included wheeling on a level surface that elicited a low rolling resistance at three different speeds (4.5, 5.5, and 6.5 km·hr-1), wheeling on a rubberized 400m track that elicited a higher rolling resistance at one speed (5.5 km·hr-1), and wheeling on a sidewalk course that included uphill and downhill segments at their self-selected speed. EE was measured using a portable indirect calorimetry system (Oxycon Mobile). Stepwise, linear regression was performed to predict EE from measured variables. A repeated measures ANOVA was used to compare the measured EE to the estimates from the power models. A leave-one-out cross validation technique was used to determine the error and bias associated with each equation. **RESULTS:** EE and power were significantly correlated (*r* = 0.694, *p* < 0.001). Stepwise, linear regression analysis yielded three significant prediction models utilizing measured power; measured power and speed; and measured power, speed, and heart rate. Cross validation analysis indicated that both the root mean squared error (rMSE) and the bias associated with each equation were low. The model that demonstrated the best agreement (*r*² = 0.87) and the lowest rMSE (rMSE = 0.74) was the model that utilized measured power, speed, and heart rate. **CONCLUSION:** EE can be accurately and precisely estimated based on hand rim propulsion power. Although the software configuration of the power meter used in this study would need modifications for long-term physical activity assessments, these results indicate that power could be used as a method to assess physical activity in people who use wheelchairs.
Measuring Physical Activity in Children with Cerebral Palsy who are Ambulatory
Margaret E. O'Neil¹, Maria A. Fragala-Pinkham², Stewart G. Trost³, Jeffrey Forman², Nancy Lennon⁴, Ameeka George⁴.¹Drexel University, Philadelphia, PA.²Franciscan Hospital for Children, Brighton, MA.³The University of Queensland, Brisbane, Australia.⁴AI duPont Hospital for Children, Wilmington, DE.
Email: moneil@drexel.edu

INTRODUCTION: Children with cerebral palsy (CP) participate in less physical activity (PA) compared to their peers with typical development. Decreased activity is related to severity of motor disability. Multiple factors contribute to lower PA levels including decreased strength and coordination; limited cardiorespiratory and muscular endurance; and decreased functional mobility and gross motor skills. Activity-based interventions are often used to promote PA in children with CP. Valid and reliable measures are needed to examine PA levels.

PURPOSE: This study examined inter-instrument reliability and concurrent validity of accelerometers relative to energy expenditure measures via indirect calorimetry in children with CP who are ambulatory.

METHODS: Twenty five children with CP (mean age = 12.7 ± 3.8 years; 44% Male) wore accelerometers bilaterally on the upper arms (BodymediaSenseWear), hips (ActiGraph GT3X) and ankles (StepWatch) and a Cosmed K4b2 portable indirect calorimeter while performing a protocol which consisted of eight physical activity trials lasting 5-6 minutes. Activity trials included resting, writing, spraying and wiping a counter, folding laundry, playing X-Box active video games, and walking at three different self-selected speeds (comfortable, brisk, fast). Intra-class coefficient correlations (ICCs) were generated to evaluate inter-instrument reliability. Spearman correlations were calculated to evaluate concurrent validity between accelerometer outputs and VO2 data. Statistical significance was set at an alpha level of 0.05.

RESULTS: Bilateral output from all three devices exhibited almost perfect agreement. ICCs ranged from 0.93 for BodyMediaSenseWear to 0.98 for ActiGraph. Validity was established between accelerometer activity and step count data and VO2 data. Spearman correlations were rho = 0.82 for vertical axis ActiGraph activity counts, rho = 0.81 for StepWatch step counts, and rho = 0.70 for BodyMedia step counts.

CONCLUSION: Accelerometry is a valid and reliable measure of PA for children with CP. Accelerometry may be useful to document PA levels in children with CP and to examine effectiveness of activity-based interventions.
Posture and physical activity measurement in youth with Cerebral Palsy: an activPAL monitor validity study
Deirdre O’Donoghue\textsuperscript{1} and Norelee Kennedy\textsuperscript{2}. \textsuperscript{1}Physiotherapy Department, Central Remedial Clinic, Dublin, Ireland, \textsuperscript{2}Department of Clinical Therapies, University of Limerick, Limerick, Ireland

INTRODUCTION: The valid measurement of posture and physical activity is important to establish accurate activity profiles of young people with Cerebral Palsy (CP). Research to date on this topic has been of low methodological quality due to use of measurement tools that have not been validated for use in the CP population. PURPOSE: To establish the validity of the activPAL physical activity monitor for the measurement of sitting, standing and walking time, transition and step number for both the affected and non/less affected lower extremity in young people with hemiplegic and diplegic CP Gross Motor Classification System (GMFCS) levels 1 and 2, using observational analysis as the reference standard. METHODS: Seventeen participants with spastic hemiplegic (n=9) and diplegic (n=8) CP GMFCS level 1 performed sitting, standing, walking and transitions in 2 controlled test protocols. Test protocols 1 and 2 involved activPAL wear on the affected limb and the non/less affected limb respectively. Both test protocols were captured by digital video recordings which were observed by two blind independent observers. The activPAL output was compared to observation data to assess the level of agreement using the Bland and Altman Method and intraclass correlation coefficients (ICC 3,1). RESULTS: Transition number measured by activPAL was identical to the observational transition number values. ICCs, Bland Altman mean differences and their upper and lower limits of agreement (ULOA and LLOA) for sitting, standing, walking time (seconds) and step count for both test protocols are tabulated as follows:

<table>
<thead>
<tr>
<th>Test 1</th>
<th>Sitting</th>
<th>Standing</th>
<th>Walking</th>
<th>Stepcount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean difference</td>
<td>-1.77</td>
<td>0.77</td>
<td>1.00</td>
<td>4.06</td>
</tr>
<tr>
<td>ULOA</td>
<td>1.44</td>
<td>4.67</td>
<td>2.84</td>
<td>8.69</td>
</tr>
<tr>
<td>LLOA</td>
<td>-4.98</td>
<td>-3.13</td>
<td>-0.84</td>
<td>-0.57</td>
</tr>
<tr>
<td>ICC</td>
<td>0.49</td>
<td>0.59</td>
<td>0.99</td>
<td>0.96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test 2</th>
<th>Sitting</th>
<th>Standing</th>
<th>Walking</th>
<th>Stepcount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean difference</td>
<td>-1.82</td>
<td>0.12</td>
<td>1.06</td>
<td>2.82</td>
</tr>
<tr>
<td>ULOA</td>
<td>1.37</td>
<td>4.92</td>
<td>4.27</td>
<td>7.68</td>
</tr>
<tr>
<td>LLOA</td>
<td>-5.01</td>
<td>-4.68</td>
<td>-2.15</td>
<td>-2.04</td>
</tr>
<tr>
<td>ICC</td>
<td>0.95</td>
<td>0.98</td>
<td>0.94</td>
<td>0.95</td>
</tr>
</tbody>
</table>
CONCLUSION: The activPAL monitor demonstrates clinically acceptable validity as a measure of transition number, sitting, standing and walking time when worn on both lower limbs. It demonstrated greater validity for standing time and lower validity for walking time when worn on the non/less affected limb. The validity of activPAL as a measure of step count for both lower limbs in this population is questionable and requires further research.
9:15 – 9:30

**Pedometer and Accelerometer Derived Steps in Free-living Older Adults with Parkinson’s disease or Osteoporosis**

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**INTRODUCTION:** Studies under controlled conditions have shown a high level of agreement between pedometer and accelerometer derived steps in individuals with normal movement pattern. However, studies on correlations between pedometer and accelerometer derived steps in older adults with impaired gait are scarce. Furthermore, to clarify the potential feasibility of these instruments for use by researchers or clinicians, there is a need to evaluate these instruments under free-living conditions. **PURPOSE:** The purpose of this study was to compare self-reported pedometer steps per day with accelerometer derived steps in free-living older adults with Parkinson’s disease (PD) or osteoporosis (OP). **METHODS:** Seventy-one participants 60 years or older with PD and 72 participants 65 years or older with OP wore a pedometer (Yamax LS2000) and an accelerometer (Actigraph GT1M or GTX3) simultaneously for one week during waking hours. Wear time and daily pedometer steps were recorded by the participants in a log sheet. Mean pedometer steps per day were compared with mean accelerometer steps. Accelerometer data was processed with ActiLife software 6. **RESULTS:** Fifty-one participants with PD (30 women; age 72.6 ± 5.3 years) and 61 participants with OP (59 women; age 75.6 ± 5.3 years) provided simultaneously recorded data for three days or more. Paired sample T-test and Wilcoxon signed rank test showed no significant difference between the two instruments in the OP-group (6035 ± 3257 and 6047 ± 2957, p = 0.956), but number of pedometer steps per day was significantly lower than accelerometer steps (4164 ± 3708 and 4967 ± 3191, p =0.002) in the PD-group. Bland-Altman plots demonstrated wide limits of agreement between the instruments in both PD (range = 6911 steps) and OP participants (range = 6794 steps). **CONCLUSION:** On a group-level there was a high agreement between self-reported pedometer steps and accelerometer derived steps in this sample of older adults with OP, but for older adults with PD the mean values for pedometer steps were systematically lower than accelerometer derived steps. The wide limits of agreement in both groups indicate that these two methods cannot be used interchangeable.

Supported by The Regional Agreement on Medical Training and Clinical Research between Stockholm County Council and KarolinskaInstitutet (ALF), and from the Swedish Research Council
Human Physical Activity Assessment Based on Sparse Representation
Shaopeng Liu\textsuperscript{1}, Robert X. Gao\textsuperscript{2}, Dinesh John\textsuperscript{3}, John Staudenmayer\textsuperscript{4}, Patty S. Freedson\textsuperscript{4}.
\textsuperscript{1}Software Science & Analytics, GE Global Research, Niskayuna, NY.\textsuperscript{2}University of Connecticut, Storrs, CT. \textsuperscript{3}Northeastern University, Boston, MA.\textsuperscript{4}University of Massachusetts, Amherst, MA.

INTRODUCTION: Machine learning techniques have been increasingly applied to physical activity (PA) assessment studies. In most of these studies, extracting and selecting the most relevant and informative features from the raw sensor signals is one of the typical and salient steps that would affect the accuracy of the devised algorithms in PA assessment. Yet it is not feasible or requires exponential computational complexity to identify the “optimal” feature subset out of a predefined “large” feature set \textit{a priori}, since it is possible to extract hundreds and thousands of features from a signal of sufficient length. PURPOSE: The purpose of the study was to design a sparse representation based multi-sensor data fusion algorithm to bypass the feature extraction and selection procedure and perform PA assessment from the raw sensor signals. METHODS: The sparse representation based method represents a PA signal to be assessed/classified as a linear combination of the training signal space, which is constructed using the original raw sensor signals instead of extracted features as performed by conventional pattern classification methods. By finding the sparsest solution (coefficients) of the linear representation, the test PA signal can be uniquely represented and therefore classified by the predefined training space. The performance of the algorithm has been evaluated through experiments with a total of 105 healthy subjects (34.7±14.2 years). Each subject wore a multi-sensor system developed in a previous study, which consists of two tri-axial accelerometers placed at the hip and wrist, and one ventilation sensor secured to the abdomen (AB) at the level of umbilicus of the test subjects. Each subject completed one of the two groups of activities of various intensities (7 activities each group with 7 minutes per activity), including sedentary, household, locomotion, and sports activities. Results were compared against conventional techniques with carefully selected feature set, including k-nearest neighbor (kNN) and support vector machines (SVM). RESULTS: When the length of the training signals was divided into 2-second intervals, the accuracy of the classification of PA types is 89.4% (with a standard deviation of 5.6% over the 105 subjects), which is greater than using longer intervals of training signals. Furthermore, the devised sparse representation based algorithm outperformed two conventional techniques (kNN and SVM) with better assessment accuracy (mean) and inter-individual variability (standard deviation). Specifically, the classification accuracies by kNN and SVM are 88.1±10.1% and 72.7±16.8%, respectively. CONCLUSION: The presented algorithm is able to provide as good and even better assessment performance as other techniques with carefully selected feature set, and it has demonstrated that the choice of an “optimal” feature set for classification is no longer critical.
Supported by NIH U01 CA130783
1:45 – 2:00

**Estimating Energy Expenditure from Heart Rate and Activity Counts: a Bayesian Approach**

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\(^1\)Columbia University, New York, NY. \(^2\)Johns Hopkins University, Baltimore, MD. \(^3\)National Institute on Aging, Baltimore, MD.

**PURPOSE:** Wearable devices promise to revolutionize the estimation of energy expenditure at the subject level by providing continuous collection of movement and heart rate data. However, several challenges currently prevent accurate estimation, including the need for subject-level calibration of the relationship between heart rate and energy expenditure and the often unclear relationship between movement and heart rate data. In this work we seek to combine multiple data sources collected as part of the Baltimore Longitudinal Study on Aging and, using a Bayesian framework, derive subject-level energy expenditure estimates that take into account subject heterogeneity. **METHODS:** In-lab calibration data is used to estimate population- and subject-level relationships between heart rate and energy expenditure (VO\(_2\) ml/kg/min) at rest and four levels of exertion. Accelerometry and heart rate data gathered over one week in a free living environment are combined to estimate the subject-specific probability of activity across heart rates and the subject-specific threshold between inactive and active. Together, these sources of data allow the estimation of energy expenditure from free living observations in a way that accounts for subject-level differences. **RESULTS:** Preliminary results indicate the importance of subject-level calibration. In particular, failing to account for subject differences can lead to the over- or under-estimation of total daily energy expenditure by more than 500 calories. It is therefore crucial to develop estimation procedures that are tailored to subject data. Additionally, early results indicate that the proposed Bayesian procedure flexibly incorporates both in-lab and free living data to estimate subject-specific activity and heart rate distributions that can lead to reasonable energy expenditure estimates. **CONCLUSIONS:** Accurate estimation of energy expenditure depends on the collection and synthesis of data from multiple sources. Subject differences are fundamentally important to understand to prevent large biases from affecting energy estimates.
INTRODUCTION: Wrist-worn accelerometers are convenient to wear and are associated with greater compliance. However, validated algorithms for predicting activity type and/or energy expenditure from wrist-worn accelerometer data are lacking. PURPOSE: To compare the activity recognition rates of an activity classifier trained on raw tri-axial acceleration signal (30 Hz) collected on the wrist versus the hip. METHODS: 52 children and adolescents (mean age 13.7 +/- 3.1 y, 28 boys, 24 girls) completed 12 activity trials that were categorized into 7 activity classes: lying down, sitting, standing, walking, running, basketball, and dancing. During each trial, participants wore an ActiGraph GT3X+ tri-axial accelerometer on the right hip and the non-dominant wrist. For both hip and wrist data, features were extracted from 10-s windows and inputted into a L1 regularized logistic regression model using R (Glmnet + L1). The average classification accuracy was calculated over 30 training-validation-testing iterations. RESULTS: Classification accuracy, averaged over all 7 activity classes, for the HIP and WRIST algorithms was 91.0 +/- 3.1 % and 88.4 +/- 3.0 %, respectively. The HIP model exhibited excellent classification accuracy for sitting (91.3%), standing (95.8%), walking (95.8%), and running (96.8%); acceptable classification accuracy for lying down (88.3%) and basketball (81.9%); and modest accuracy for dance (64.1%). The WRIST model exhibited excellent classification accuracy for sitting (93.0%), standing (91.7%), and walking (95.8%); acceptable classification accuracy for basketball (86.0%); and modest accuracy for running (78.8%), lying down (74.6%) and dance (69.4%). CONCLUSION: Activity recognition was marginally higher using raw tri-axial acceleration signal from the hip versus the wrist. However, the small difference in performance may not be of practical significance in field-based studies. Both algorithms achieved acceptable classification accuracy. Supported by NIH RO1 NICHD 55400
Support Vector Machines Classifiers Of Physical Activities In Preschoolers
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¹Department of Epidemiology and Biostatistics, Drexel University, Philadelphia, PA 19120
²USDA/ARS Children’s Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, TX 77030

INTRODUCTION: Novel approaches to classify physical activities in young children are essential for identifying their characteristically sporadic physical activity patterns. Cost-effective, non-intrusive, valid and precise methods for the classification of physical activities in preschool-aged children are essential to determine physical activity behaviors, prevalence and determinants, dose-response relationships between physical activity and health outcomes, and intervention effectiveness. PURPOSE: The goal of this study is to develop, test, and compare multinomial logistic regression (MLR) and support vector machines (SVM) in classifying preschool-aged children physical activity data acquired from an accelerometer.

METHODS: 69 children aged 3 to 5 years old were asked to participate in a supervised protocol of physical activities while wearing a triaxial accelerometer (ActiGraph GT3X+). Accelerometer counts, steps and position were obtained from the device. We applied -means clustering to determine the number of natural groupings presented by the data. We used MLR and SVM to classify the six activity types. Using direct observation as the criterion method, the 10-fold cross validation (CV) error rate was used to compare MLR and SVM classifiers, with and without sleep. RESULTS: Altogether, 58 classification models based on combinations of the accelerometer output variables were developed. In general, the SVM classifiers had a smaller 10-fold CV error rate than their MLR counterparts. Including sleep, a SVM classifier provided the best performance with a 10-fold CV error rate of 24.70%. Without sleep, a SVM classifier based triaxial accelerometer counts, vector magnitude, steps, position and 1- and 2-minute lag and lead values achieved a 10-fold CV error rate of 20.16% and an overall classification error rate of 15.56%. CONCLUSION: SVM supersedes the classical classifier MLR in categorizing physical activities in preschool-aged children. Using triaxial accelerometer data, SVM can be used to correctly classify physical activities typical of preschool-aged children with an acceptable classification error rate.

Supported by USDA/ARS under Cooperative Agreement No. 58-6250-0-008 and National Institutes of Health (NIH) Grant number R01 DK085163
INTRODUCTION: Laboratory-based polysomnography (PSG) is the gold standard technique for assessment and quantification of sleep. Wrist and hip actigraphy have been widely used to quantify sleep and physical activity, respectively. It remains unclear whether hip actigraphy is also a valid measure of sleep. PURPOSE: To compare sleep variables simultaneously derived from PSG, wrist actigraphy and hip actigraphy in healthy, young adults. METHODS: 72 healthy individuals (49% females) aged 22.0±0.2 years (mean±SD) were recruited from the Raine Study, a population-based pregnancy cohort study in Western Australia. Each underwent in-laboratory PSG while simultaneously wearing one GTX3+ actigraph (Actigraph, Florida, USA) on their non-dominant wrist and another on an elastic belt on the right hip. Estimates of sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO), and sleep efficiency (SE) were derived using standard proprietary equations for count based actigraphy and standard PSG definitions. The sensitivity and specificity of actigraphic estimates of sleep versus polysomnography-defined sleep were also assessed on a 60 second epoch-by-epoch basis.

<table>
<thead>
<tr>
<th></th>
<th>PSG</th>
<th>Wrist</th>
<th>Hip</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOL (min)</td>
<td>17.8 ± 14.1&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>9.5 ± 9.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.1 ± 3.9</td>
</tr>
<tr>
<td>WASO (min)</td>
<td>41.5 ± 45.8&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>56.5 ± 44.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.2 ± 18.4</td>
</tr>
<tr>
<td>TST (min)</td>
<td>392.5 ± 63.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>383.8 ± 64.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>434.4 ± 54.0</td>
</tr>
<tr>
<td>SE (%)</td>
<td>86.7 ± 10.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>85.3 ± 10.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>96.5 ± 4.5</td>
</tr>
</tbody>
</table>

a = PSG vs wrist; b= PSG vs hip; c = wrist vs hip (all p<0.05)

RESULTS: Relative to PSG measures: SOL was underestimated by wrist and hip actigraphy; WASO was overestimated by wrist but underestimated by hip actigraphy; and TST and SE were similar by wrist actigraphy but overestimated by hip actigraphy (see Table). Compared to wrist actigraphy, SOL and WASO were less but TST and SE more when measured by hip actigraphy. The sensitivity, specificity and accuracy of wrist actigraphy were 91%, 44% and 85%, respectively and of hip actigraphy were 98%, 13% and 86%, respectively. CONCLUSION: A hip-worn GT3X+ actigraph can not be used to accurately measure sleep variables in young adults using the standard equations due to its very poor ability to detect wakefulness during sleep. Although wrist actigraphy is widely used in both clinical and research settings the present study shows it to have a limited capacity to detect periods of wake during sleep when using standard equations. Supported by: National Health & Medical Research Council Australia (No. 1027449)
Affordable Sleep Estimates using Micro-Electro-Mechanical-Systems (MEMS) Accelerometry
Bart HW teLindert, Eus JW van Someren. Netherlands Institute for Neuroscience, Amsterdam, Netherlands.
Email: b.te.lindert@nin.knaw.nl

INTRODUCTION: Although more affordable than polysomnography, actigraphic sleep estimates have disadvantages. Brand-specific differences in data reduction impede pooling of data for consortia to create large-scale cohorts, as for genome-wide-association-studies (GWAS). Secondly, online data reduction may not fully exploit movement information. Thirdly, sleep estimate reliability might improve by advanced analyses of tri-axial, linear accelerometry data sampled at a high rate. Such recordings are now feasible using affordable micro-electro-mechanical-systems (MEMS). However, it might take a while before advanced analyses are validated and available. PURPOSE: To provide lab-databases and ongoing studies with backward compatibility when switching from actigraphy to MEMS accelerometry, we designed and validated a method to transform accelerometry data into the traditional actigraphic ‘movement counts’, thus allowing for the use of validated algorithms to estimate sleep parameters.

METHODS: Simultaneous duplicate actigraphy and duplicate MEMS-accelerometry was recorded in fifteen healthy adults (23-36 years, 10M, 5F) during one night spent at home. Actigraphy was recorded as ‘movement counts’/15-seconds epoch with two Actiwatches (Cambridge Neurotechnology Ltd., Cambridge, UK). MEMS-accelerometry was digitized at 50 Hz with two Geneactivs (ActivInsights Ltd., Kimbolton, UK). Passing-Bablok regression was used to optimize the transformation of MEMS-accelerometry signals to ‘movement counts’. Actigraphic ‘movement counts’ and their MEMS-accelerometry estimates were used to calculate common sleep parameters. Reliability was evaluated both between and within the traditional actigraphs and MEMS-accelerometers using Bland-Altman plots.

RESULTS: Movement counts could be estimated from MEMS-accelerometry with high precision. MEMS-accelerometry had a better reliability than actigraphy; sleep parameter estimate agreement between two MEMS-accelerometers or a MEMS-accelerometer and an actigraph was better than agreement between two actigraphs. CONCLUSION: The algorithm allows for continuity of outcome parameters in ongoing actigraphy studies that consider switching to the new generation of MEMS-accelerometers. Their affordability and the algorithm with graphical-user-interface we here provide, makes objective sleep estimates in large-scale twin-sibling and GWAS cohort designs feasible.

SUPPORTED BY: Project NeuroSIPE 10738, of the Dutch Technology Foundation STW; and by the VICI Innovation Grant 453-07-001 of the Netherlands Organization of Scientific Research (NWO); The Hague, the Netherlands
Do Active Children Sleep More? A Cross-sectional, Longitudinal Analysis Using Accelerometry
Email: rachael.taylor@otago.ac.nz

INTRODUCTION: Although it makes intuitive sense that participating in physical activity would promote better sleep, existing cross-sectional data have produced conflicting results. PURPOSE: To determine the relationships between objectively measured sleep and physical activity in young children followed from 3 to 7 years of age. METHODS: Repeated measures of physical activity and sleep were obtained by accelerometry in 242 children at 3, 4, 5, 5.5, 6.5 and 7 years of age. Children wore the accelerometer during all waking and sleeping hours for 5 days at each time point. Estimates of sleep duration were obtained using the Sadeh algorithm (Actilife). Physical activity was measured during awake hours only using the MeterPlus data reduction programme (counts per minute (cpm), time in sedentary, light, moderate and vigorous categories). Bi-plots were used to illustrate the relationship between sleep and physical activity. Multiple linear regression examined cross-sectional and longitudinal relationships adjusting for demographics and family characteristics. RESULTS: Data were available for a total of 7801 days from 242 children. Year-to-year tracking correlations ranged from r = 0.26-0.55 for hours of sleep, and r = 0.05-0.40 for measures of physical activity. Bi-plots suggested that sleep duration was not related to moderate-vigorous physical activity at any age, but rather was more closely aligned with time in sedentary or light activity. The bi-plots also showed that periods of night wakefulness were independent of day-time physical activity. Cross-sectional analyses showed that longer sleep duration was associated with lower activity (cpm), both before and after adjustment for confounders (P < 0.001). Ethnic minority children also slept less (P = 0.033-0.008). Longitudinal analyses used “average” cpm (at ages 3, 4 and 5) to predict sleep at 7 years of age. Children who slept more at age 7 did significantly less activity when aged 3-5 (P = 0.033) in univariate analyses, but this was no longer significant once adjusted for confounders (P = 0.129). A greater number of children in the household predicted less sleep at 7 years (P = 0.018). CONCLUSIONS: More active children do not sleep for longer periods at night than less active children, and in fact the reverse may be true. However, these analyses are complicated by the closed nature of the data; over a 24-hour period, if one time component increases (such as sleep duration), then at least one of the awake time components (ie. sedentary, light, moderate or vigorous time) must decrease. Thus it is uncertain whether the negative correlations observed are genuine, or simply an artefact of analyzing 24-hour time data.
Validation of the Zephyr Bioharness to Measure Obstructive Sleep Apnea Compared to Laboratory-Based Polysomnography

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Obstructive sleep apnea (OSA) is a major public health concern, but remains underdiagnosed and untreated due, in part, to the high cost, invasiveness, and inconvenience of the “gold standard” diagnostic tool, laboratory-based polysomnography (PSG). The Zephyr Bioharness is a chest-worn strap that captures physiological parameters, including heart rate, and breathing frequency and volume. The Zephyr Bioharness is commonly used to assess daytime activity metrics including energy expenditure and ventilatory thresholds. PURPOSE: To establish the diagnostic utility of the Zephyr Bioharness to identify apnea or hypopnea events with the criterion measure of laboratory-based PSG scored by certified technicians under the supervision of a board certified sleep specialist. METHODS: Participants were referred to the Mayo Clinic Arizona Sleep Disorders Center for suspected OSA. Eligibility criteria included being 35-60 years of age, BMI 27-35 kg/m², free of previous diagnosis of OSA or current CPAP use, other comorbid sleep disorder, or neurological disease. Stepwise non-linear mixed model (events nested within persons) analyses were used to develop an algorithm to predict PSG-scored apnea or hypopnea events from Zephyr biomeasures. The diagnostic utility of these models were assessed using area under the curve (AUC) for receiver operator characteristic (ROC) analyses. RESULTS: Participants (N=24) were 54% men, 67% Caucasian, 39-60 years of age (mean age = 55.4 ± 5.4 years), 63% obese (mean BMI=30.6 ± 2.9 kg/m²), and 83% at ‘high risk’ for OSA (mean STOP-BANG score = 4.3 ± 1.7). Multivariate model results suggested that breathing frequency \( t = -2.81, p = .005 \) and breathing volume \( t = -8.05, p < .001 \) were independent predictors of apneas or hypopneas. Heart rate approached significance \( t = 1.75, p = .08 \) but was not retained for ROC modeling. ROC analysis suggested that breathing frequency and volume produced good accuracy for classifying apnea or hypopnea events (AUC [SE] = .86[.0009], \( p < 0.0001 \)). CONCLUSION: The Zephyr Bioharness may be a viable complement to laboratory-based PSG for diagnosis and ongoing assessment of OSA. Its utility may be particularly relevant for individuals with inadequate health insurance or persons living in rural areas where PSG is not feasible. Future work includes the development of a cloud-based platform that leverages the built-in bluetooth capabilities of the Zephyr Bioharness to allow for remote monitoring of OSA symptoms for healthcare providers.