Visualising children's time use patterns and their association with obesity status, travel mode and neighbourhood context

Zhao, Jinfeng; Mavoa, Suzanne; Chang, Kevin; Mackay, Lisa; Stewart, Tom, Ikeda, Erika; Donnellan, Niamh; Smith, Melody

jinfeng.zhao@auckland.ac.nz

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

MEDICAL AND HEALTH SCIENCES

Visualising children's time use patterns and their association with obesity status, travel mode and neighbourhood context

1. Background
2. Aim and Methods
3. Visualisation techniques
4. Discussion and Conclusions

Background – Accelerometer data

- Physical activity is fundamental to health, development and well-being in children.[1]
- Accelerometers are devices that measure proper acceleration* and are increasingly being used to measure physical activity and sedentary behaviour.[1,2]
- The growing quantity of such data provides both opportunities and challenges for turning data into information and knowledge.

*Proper acceleration is the acceleration of a body in its own instantaneous rest frame

[1] Oliver, M. et al. (2016). Neighbourhoods for Active Kids: study protocol for a cross-sectional examination of neighbourhood features and children's physical activity, active travel, independent mobility and body size. BMJ Open, 6(8)
[2] Maddison, R. et al. (2017). Quantifying Human Movement Using the Movn Smartphone App: Validation and Field Study. JMIR Mhealth Uhealth, 5(8), e122.

Background – Duration and timing of activities

Accelerometer data are often analysed by duration of activity,[3] i.e. what people are doing and for how long.

However, the timing of activities is also important and has an impact on health.

- For example, research found that obese individuals are more likely to work during hours that are typically devoted to sleep (e.g. 2 am to 7 am).[4]

Timing includes the time of day that activities take place and their sequence.

[3] Chastin, S. F. M., Palarea-Albaladejo, J., Dontje, M. L., & Skelton, D. A. (2015). Combined Effects of Time Spent in Physical Activity, Sedentary Behaviors and Sleep on Obesity and Cardio-Metabolic Health Markers: A Novel Compositional Data Analysis Approach. PLoS ONE, 10(10), e0139984.

[4] Patel, V. C., & Spaeth, A. M. (2016). Relationships between Time Use and Obesity in a Representative Sample of Americans. *Obesity (Silver Spring, Md.), 24*(10), 2164-2175.

Background - Active travel to School (ATS)

- ATS is an important source of physical activity.
- ATS is associated with a healthier body composition and higher levels of cardiorespiratory fitness among children.[5]
- ATS refers to walking, cycling, scootering, skateboarding or any similar travel mode where human energy is spent.
- Passive travel to school is the opposite.

[5] Lubans, D.R., et al., The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. International Journal of Behavioral Nutrition and Physical Activity, 2011. 8(1): p. 5.

Background - Distance between home and school

- The distance between home and school is the most consistent predictor of active travel to school in children: the closer that children live to school, the more likely they are to use active travel.[6]

[6] Duncan S., et al, Active Transport, Physical Activity, and Distance Between Home and School in Children and Adolescents. J Phys Act Health. 2016 Apr;13(4):447-53

Background – NZ Indices of Multiple Deprivation

Area level deprivation measures such as the New Zealand Indices of Multiple Deprivation (IMD)[7] help us to understand contextual information which may have an impact on an individual's well-being.

IMD is a small-area index of socioeconomic deprivation:

- It is based on seven Domains of deprivation: Employment; Income; Crime; Housing; Health; Education; and Geographical Access.
- It uses 28 indicators of deprivation derived from data sources such as national health, social development, taxation, education, police, geospatial and the 2013 Census.

[7] Exeter, D. J., Zhao, J., Crengle, S., Lee, A., & Browne, M. (2017). The New Zealand Indices of Multiple Deprivation (IMD): A new suite of indicators for social and health research in Aotearoa, New Zealand. PLoS ONE, 12(8), e0181260. 10.1371/journal.pone.0181260

Background – Compositional nature of activities

Time is a finite and scarce resource that shapes people's daily lives as they schedule various activities. How they use their time is a major determinant of people's well-being and health.

Given a 24-hour daily time budget, time spent on one activity has an impact on the availability of time for other activities, so daily activities are collinear and co-dependent.

Daily activities should be analysed and conceptualised within this compositional paradigm to achieve meaningful findings.[3]

[3] Chastin, S. F. M., Palarea-Albaladejo, J., Dontje, M. L., & Skelton, D. A. (2015). Combined Effects of Time Spent in Physical Activity, Sedentary Behaviors and Sleep on Obesity and Cardio-Metabolic Health Markers: A Novel Compositional Data Analysis Approach. PLoS ONE, 10(10), e0139984.

Aim

We aim to visualise compositional time use patterns of children's daily activities in relation to their obesity status, active/passive travel mode, distance to school and neighborhood context, such as area level deprivation, using accelerometer data collected from the Neighbourhoods for Active Kids (NfAK) project[1].

Time use was divided into four activities: (1) moderate to vigorous physical activity (MVPA), (2) light intensity physical activity (LIPA), (3) sedentary behaviour (SB) and (4) sleep.

[1] Oliver, M. et al. (2016). Neighbourhoods for Active Kids: study protocol for a cross-sectional examination of neighbourhood features and children's physical activity, active travel, independent mobility and body size. BMJ Open, 6(8)

Methods - Data

The accelerometer data used in this research were:

- For about 900 children aged 9 to 12 years
- Collected over 7-days at 30 second intervals
- Linked to variables such as:
  - interviewed children's sleep times
  - derived physical and sedentary activities
  - surveyed general travel mode to school
    - active travel
    - passive travel
  - deprivation, with quintile 5 (Q5) being the 20% most deprived areas in New Zealand.

[1] Oliver, M. et al. (2016). Neighbourhoods for Active Kids: study protocol for a cross-sectional examination of neighbourhood features and children's physical activity, active travel, independent mobility and body size. BMJ Open, 6(8)

Methods - Visualisation

The data are very rich, involving space, cyclic time, compositional activities, body size, travel mode, distance between home and school and neighborhood-level deprivation.

The complexity and characteristics of the data require novel visualisation techniques to reveal integrated time use patterns.

We developed two strategies to visualise our data:

- We applied novel ringmap visualisation techniques to overview the data and compare spatial, temporal and activity patterns among sub-groups;
- We developed a new visualisation technique, called a time-activity diagram, to visualise and compare data at a finer resolution and reveal timing and activity patterns at both the individual and aggregated levels.

Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

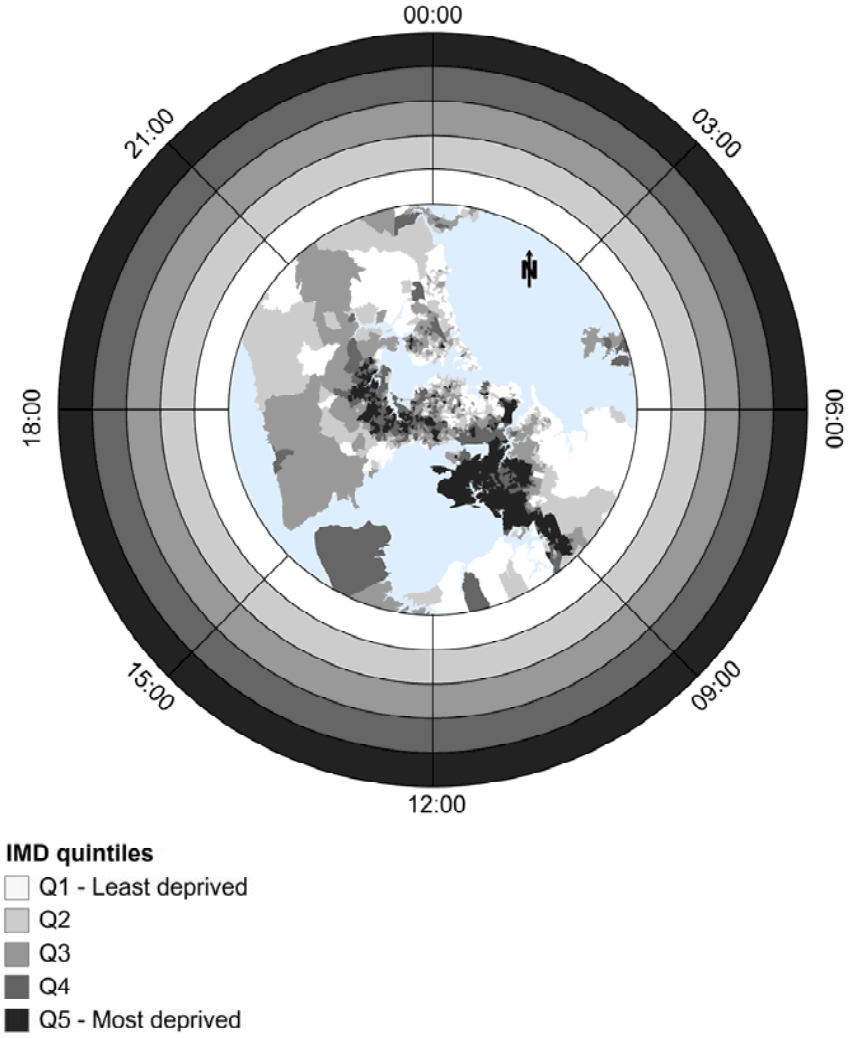
A ringmap visualisation is made up of a geographical map in the center and surrounding rings.

The geographical map shows the main urban areas in Auckland City, New Zealand.

The white to black shades represent quintiles of deprivation. IMD quintile 1 (white) is the least deprived and quintile 5 (black) is the most deprived in both the inset map and the 5 rings.

Each ring represents a 24-hour day for children who lived in areas with the corresponding IMD quintile.

Rings are divided into eight 3-hour time blocks ordered clockwise from midnight at the top.



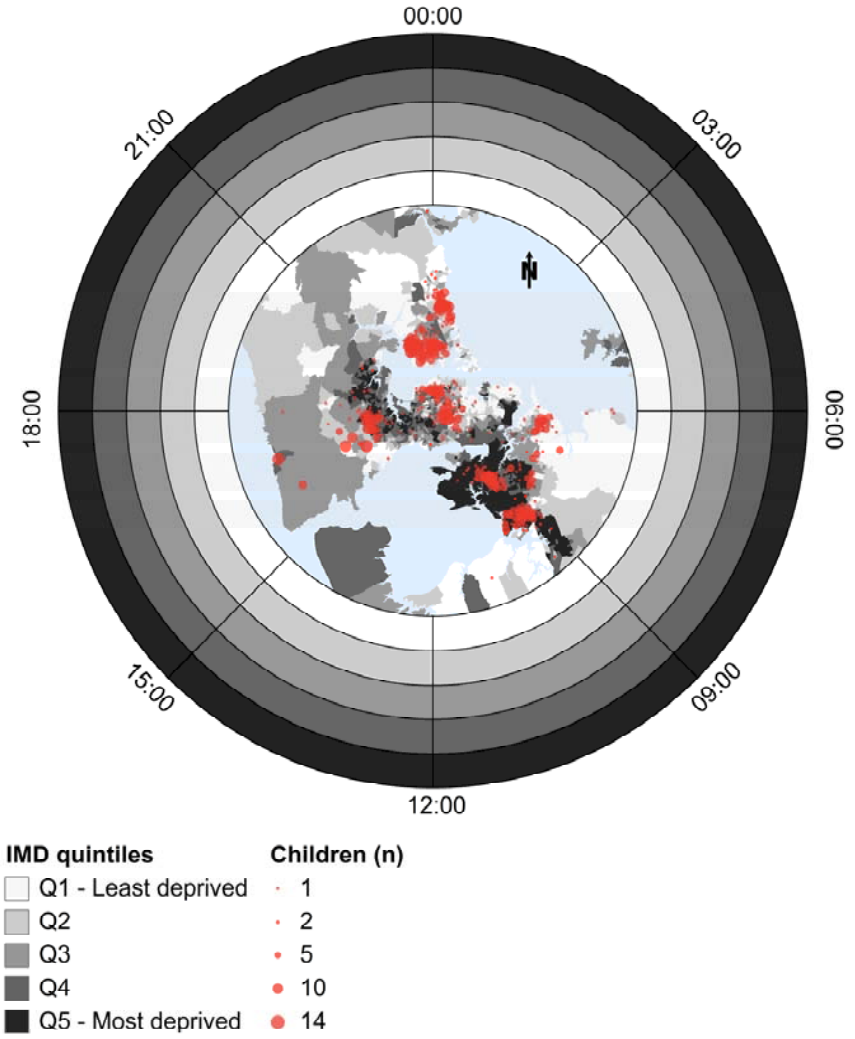
Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

Data zones are a base geography constructed for social and health research in New Zealand using relevant zone design criteria.

They have populations ranging from 500 to 1,000

Children's home addresses were aggregated to data zones to protect their privacy.

Proportional semi-transparent circles (red) represent the number of children in each data zone. They are overlaid on the geographical map to associate children's home address with deprivation.



Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

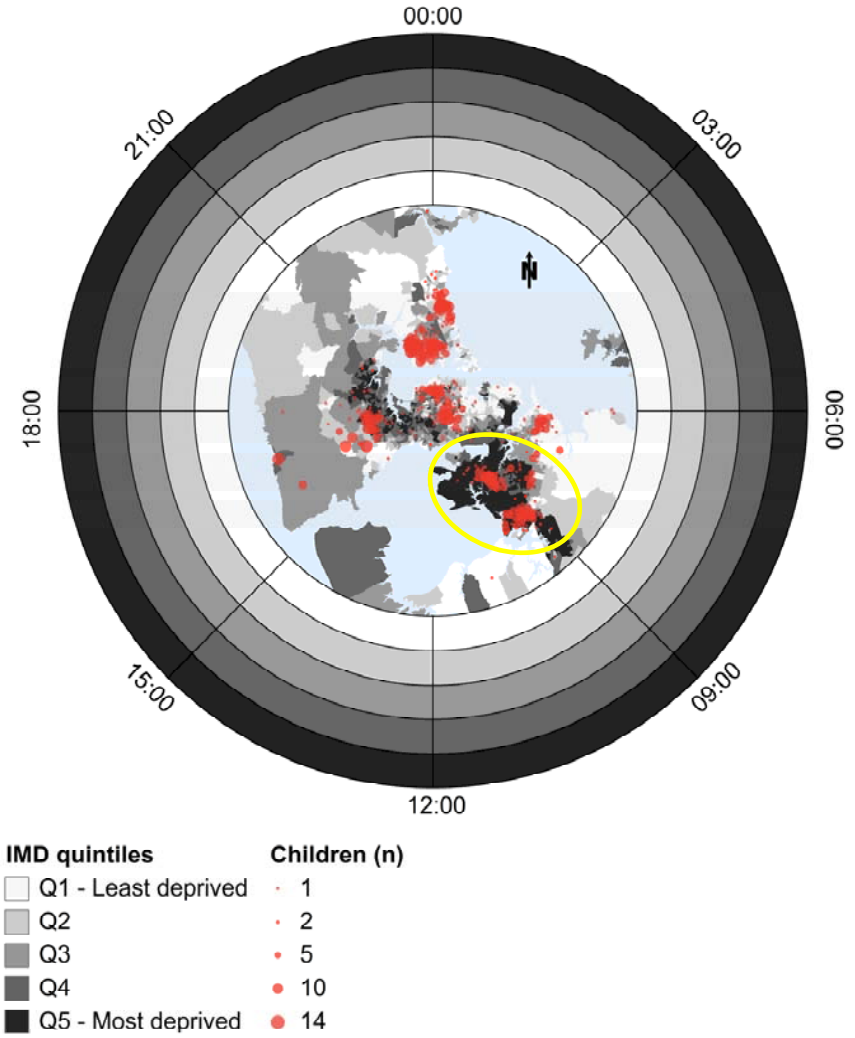
Data zones are a base geography constructed for social and health research in New Zealand using relevant zone design criteria.

They have populations ranging from 500 to 1,000

Children's home addresses were aggregated to data zones to protect their privacy.

Proportional semi-transparent circles (red) represent the number of children in each data zone. They are overlaid on the geographical map to associate children's home address with deprivation.

For example, most Q5 children lived in South Auckland (in the black area at the bottom of the inset map).

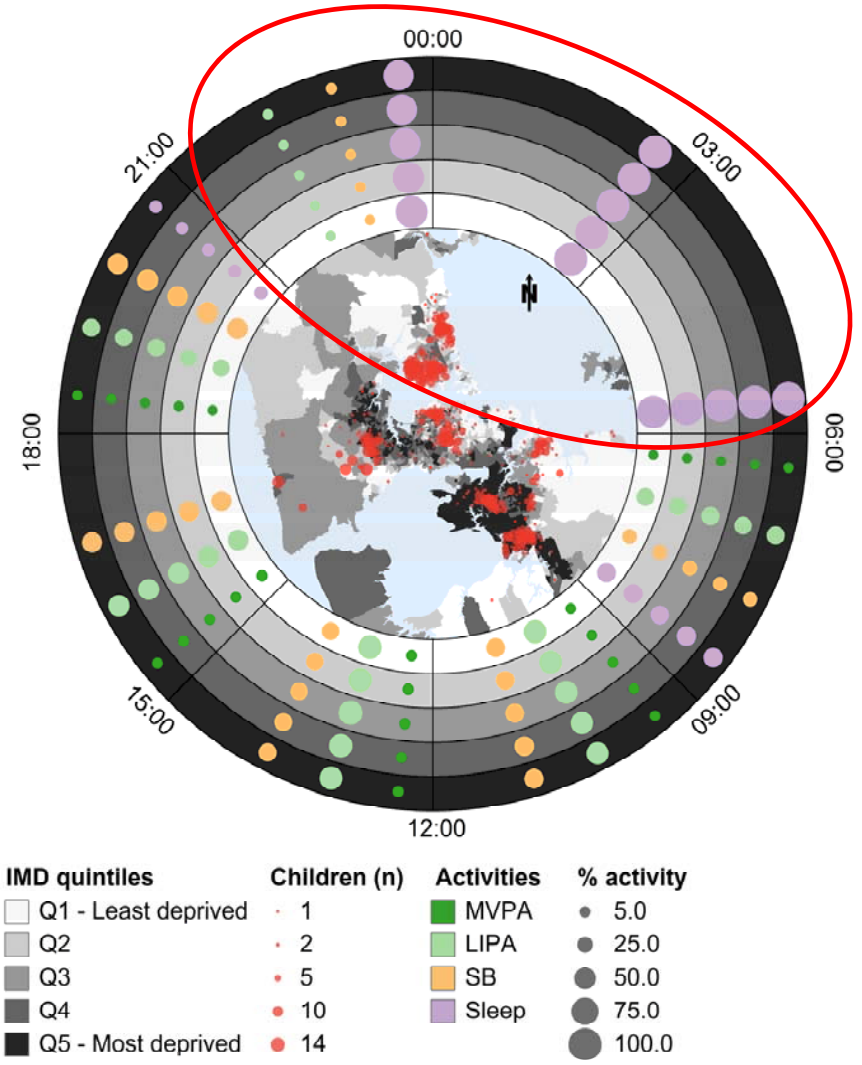


Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

In each 3 hour time block, the average percentage of time spent on each activity is displayed using proportional coloured circles: MVPA (dark green), LIPA (light green), SB (orange) and sleep (purple).

In each time block, the time spent on the four activities adds up to 100%. Activities that comprise less than 1% of each time block are suppressed for clarity.

As you would expect, the time spent on sleeping takes up the first 2 time blocks (00:00 to 06:00) and dominates the last time block (21:00 to 24:00).



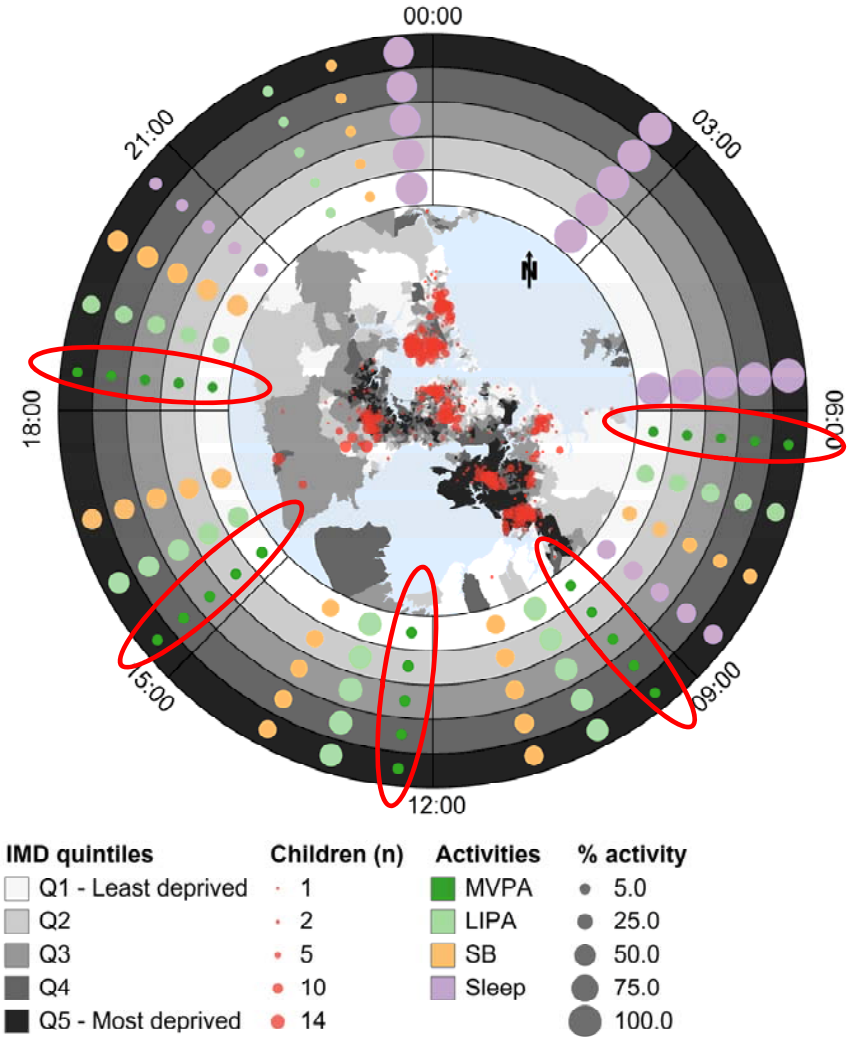
Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

In each 3 hour time block, the average percentage of time spent on each activity is displayed using proportional coloured circles: MVPA (dark green), LIPA (light green), SB (orange) and sleep (purple).

In each time block, the time spent on the four activities adds up to 100%. Activities that comprise less than 1% of each time block are suppressed for clarity.

As you would expect, the time spent on sleeping takes up the first 2 time blocks (00:00 to 06:00) and dominates the last time block (21:00 to 24:00).

In each time block, the percentage of time spent on moderate to vigorous physical activities (MVPA) is the smallest.



Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

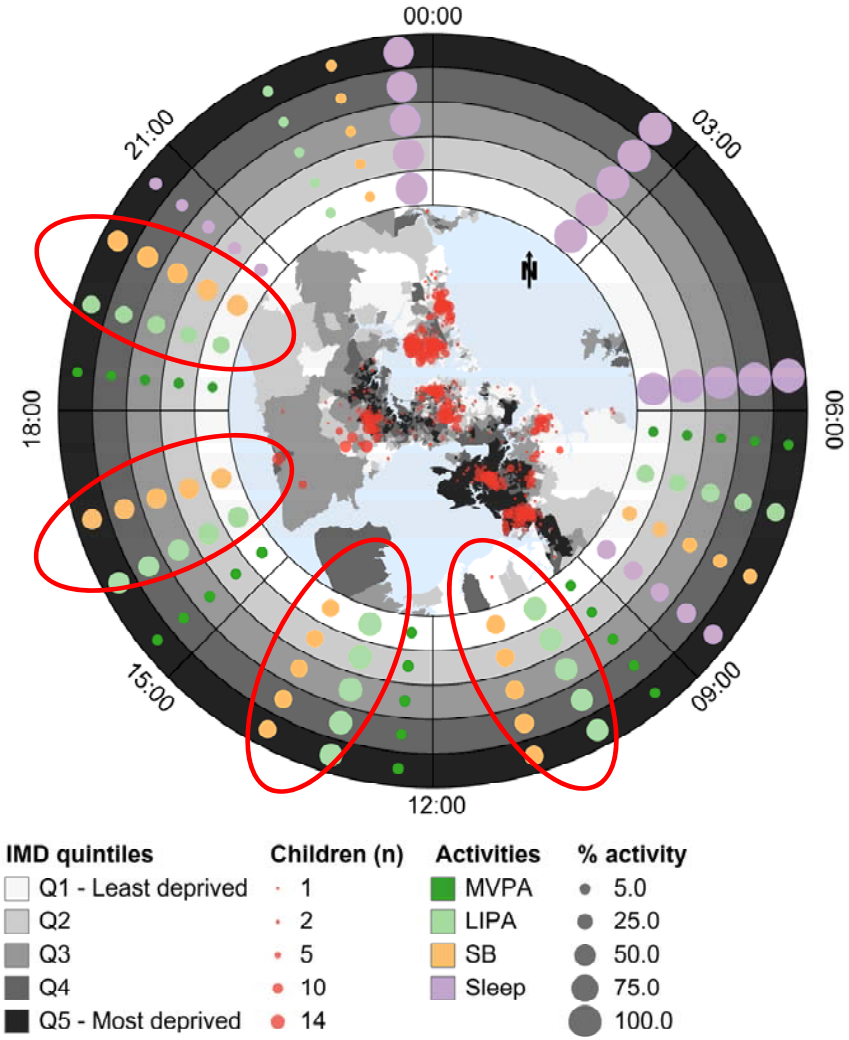
In each 3 hour time block, the average percentage of time spent on each activity is displayed using proportional coloured circles: MVPA (dark green), LIPA (light green), SB (orange) and sleep (purple).

In each time block, the time spent on the four activities adds up to 100%. Activities that comprise less than 1% of each time block are suppressed for clarity.

As you would expect, the time spent on sleeping takes up the first 2 time blocks (00:00 to 06:00) and dominates the last time block (21:00 to 24:00).

In each time block, the percentage of time spent on moderate to vigorous physical activities (MVPA) is the smallest.

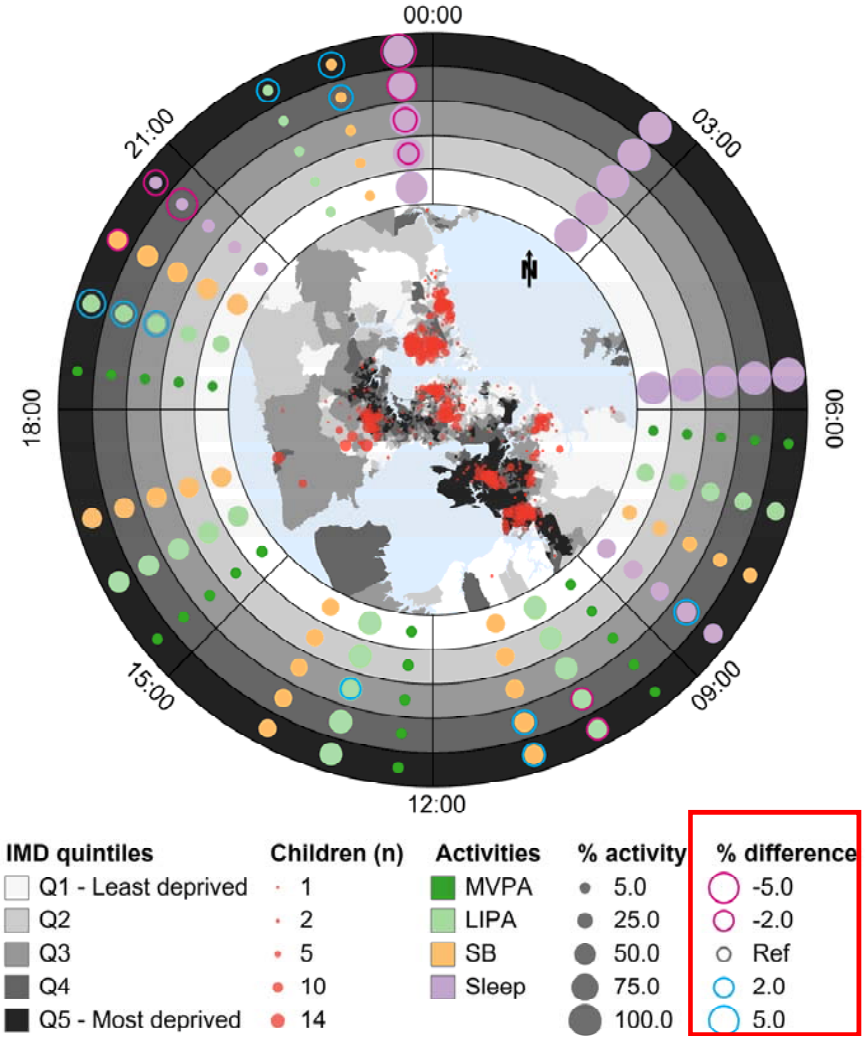
Light intensity physical activities (LIPA) and sedentary behaviour (SB) dominate the four time blocks from 09:00 to 21:00, with more time spent on LIPA during school hours.



Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

To facilitate comparison between the same activity in the same time block, proportional rings are added to represent the difference in the % of time spent on each activity compared to that of deprivation quintile 1 (the reference).

Purple rings represent a % less than Q1 and blue rings a % greater than Q1 (differences of <2% are suppressed).

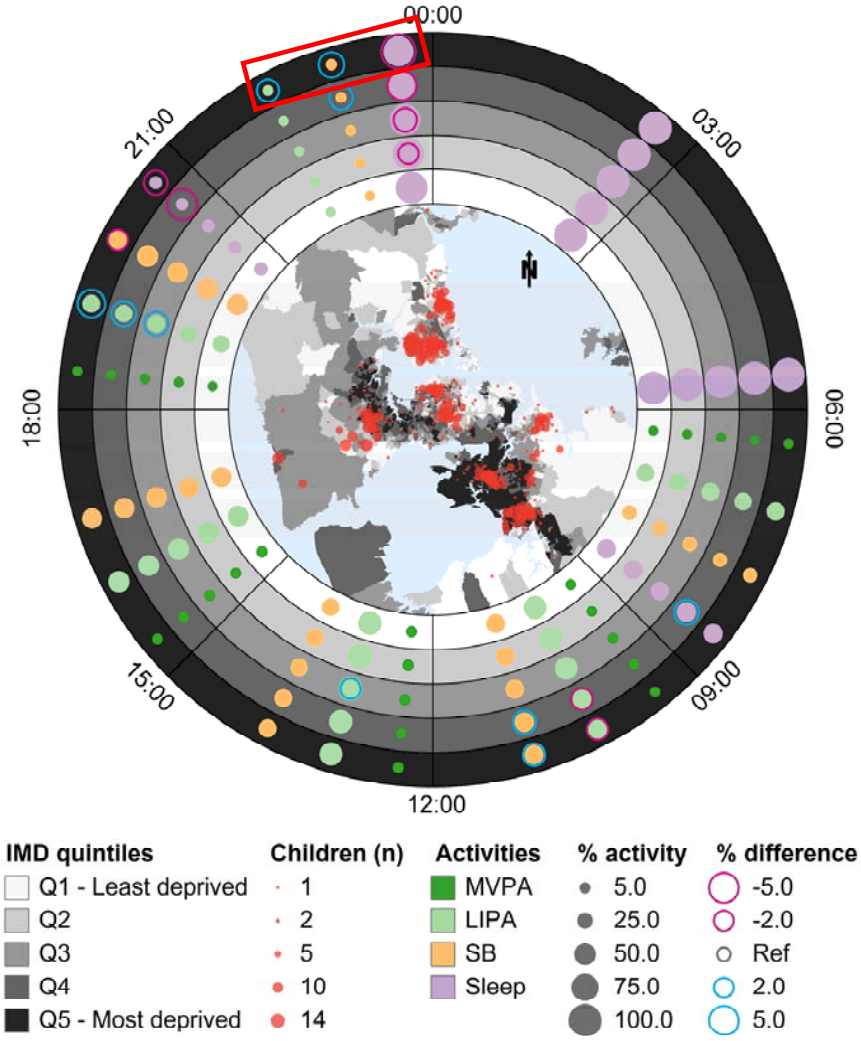


Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

To facilitate comparison between the same activity in the same time block, proportional rings are added to represent the difference in the % of time spent on each activity compared to that of deprivation quintile 1 (the reference).

Purple rings represent a % less than Q1 and blue rings a % greater than Q1 (differences of <2% are suppressed).

For example, in the time block from 21:00 to midnight, children in quintile 5 sleep the least (with the largest purple ring) and spend more time on SB and LIPA (with the large blue rings).



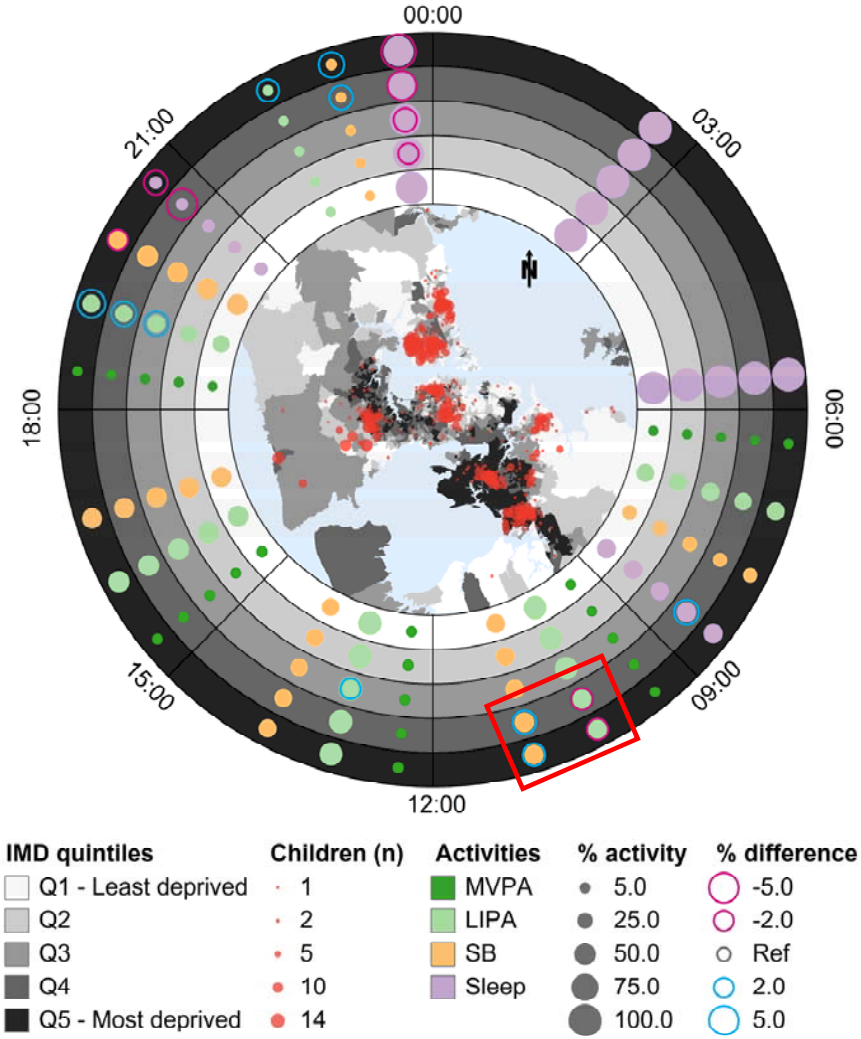
Using a ringmap to visualize spatial and temporal activity patterns over 24 hours on weekdays for 882 children, and their association with deprivation.

To facilitate comparison between the same activity in the same time block, proportional rings are added to represent the difference in the % of time spent on each activity compared to that of deprivation quintile 1 (the reference).

Purple rings represent a % less than Q1 and blue rings a % greater than Q1 (differences of <2% are suppressed).

For example, in the time block from 21:00 to midnight, children in quintile 5 sleep the least (with the largest purple ring) and spend more time on SB and LIPA (with the large blue rings).

Between 09:00 and 12:00, children in quintiles 4 and 5 spent relatively more time on SB (with the large blue rings) and less time on LIPA (with the large purple rings) than children in the other three quintiles.



Time-Activity diagram – Visualising aggregated patterns at a finer scale

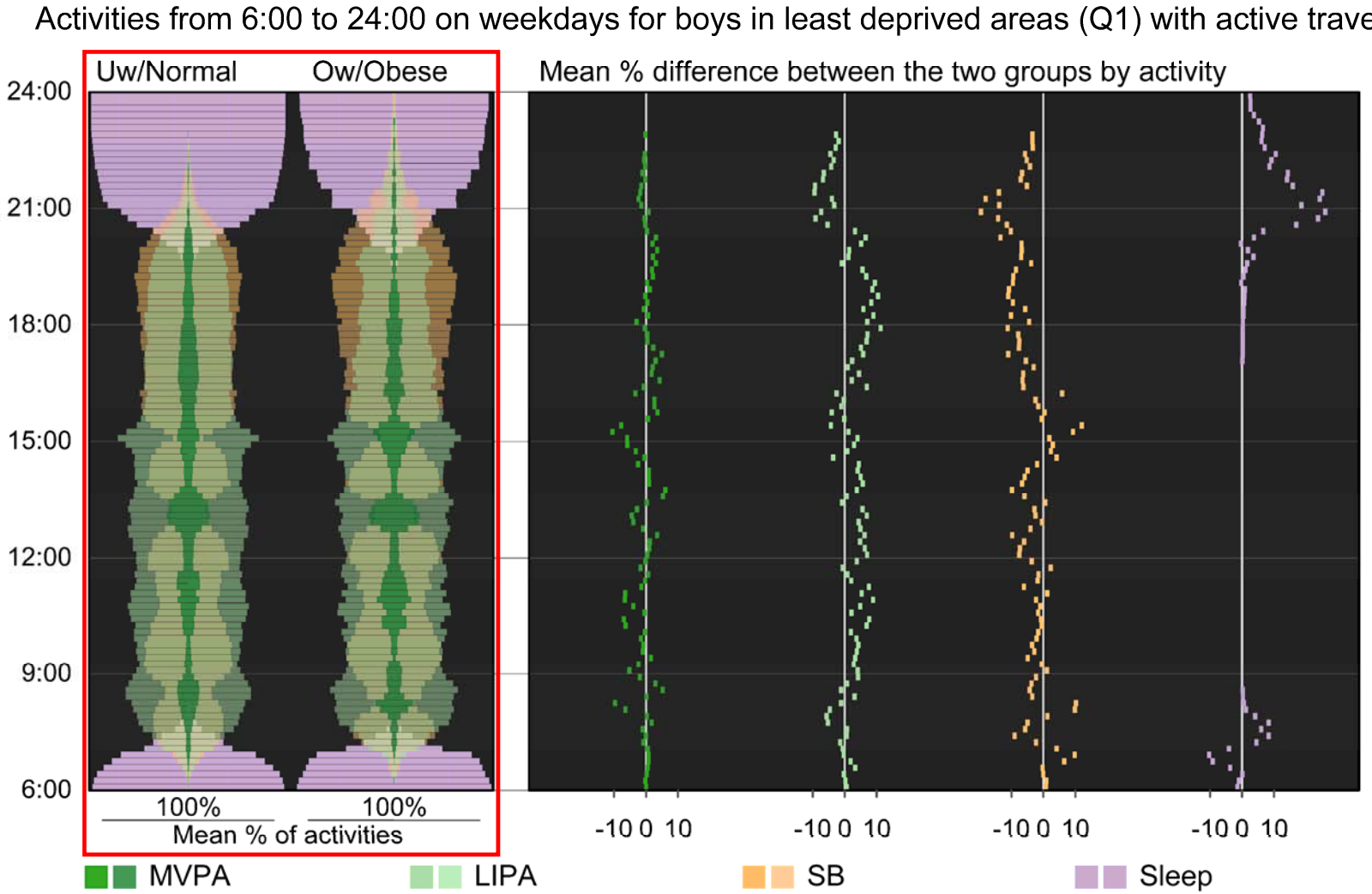
This is a time-activity diagram. It presents aggregated time use patterns of activities for the two population groups (Uw/Normal and Ow/Obese boys).

The diagram is configured as two panels:

The smaller left panel shows the aggregated mean % of time spent on the different activities for the two groups.

The mean % of time is presented as proportional bandwidth.

The % of time sums to 100%.



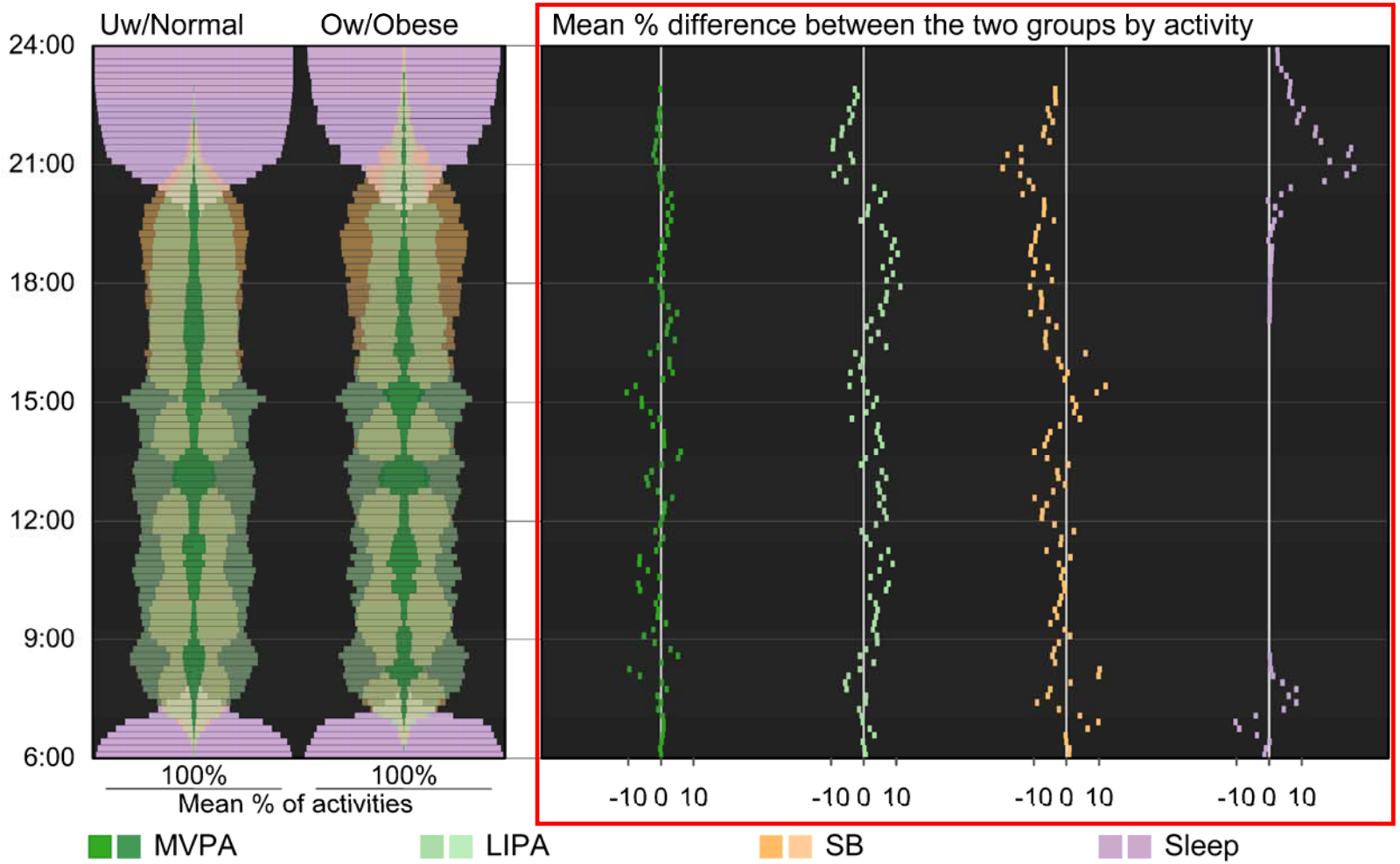
Time-Activity diagram – visualising aggregated patterns at a finer scale

The right panel shows the % difference between the two groups for each activity type.

The % difference = % Uw/Normal group - % Ow/Obese group.

Any results that appear on the right hand side of the zero axis indicate that the % of time spent on that activity was greater among Uw/Normal children.

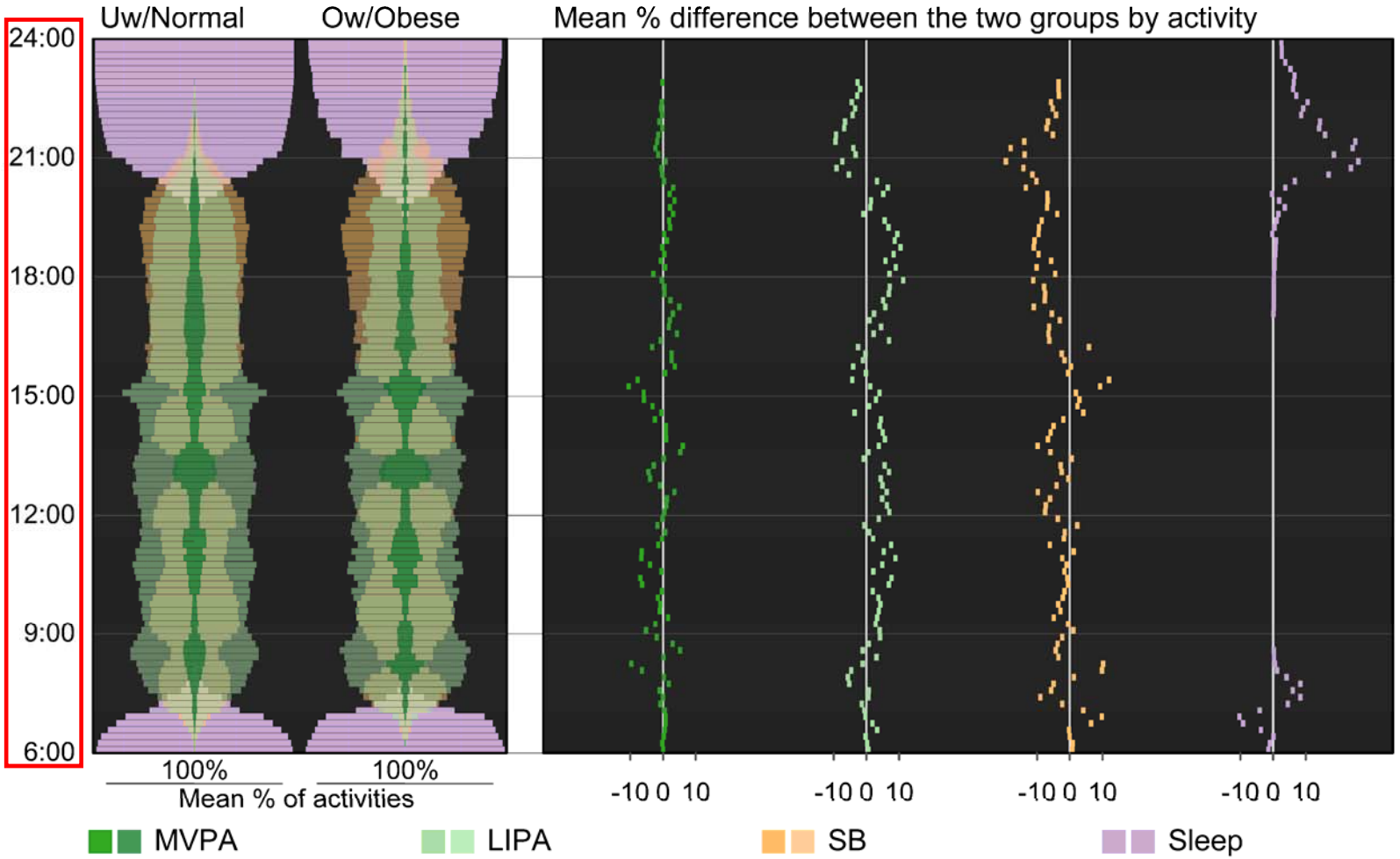
Activities from 6:00 to 24:00 on weekdays for boys in least deprived areas (Q1) with active travel



Time-Activity diagram – visualising aggregated patterns at a finer scale

The vertical dimension of the visualisation shows time of day from 6am at the bottom to midnight.

Activities from 6:00 to 24:00 on weekdays for boys in least deprived areas (Q1) with active travel

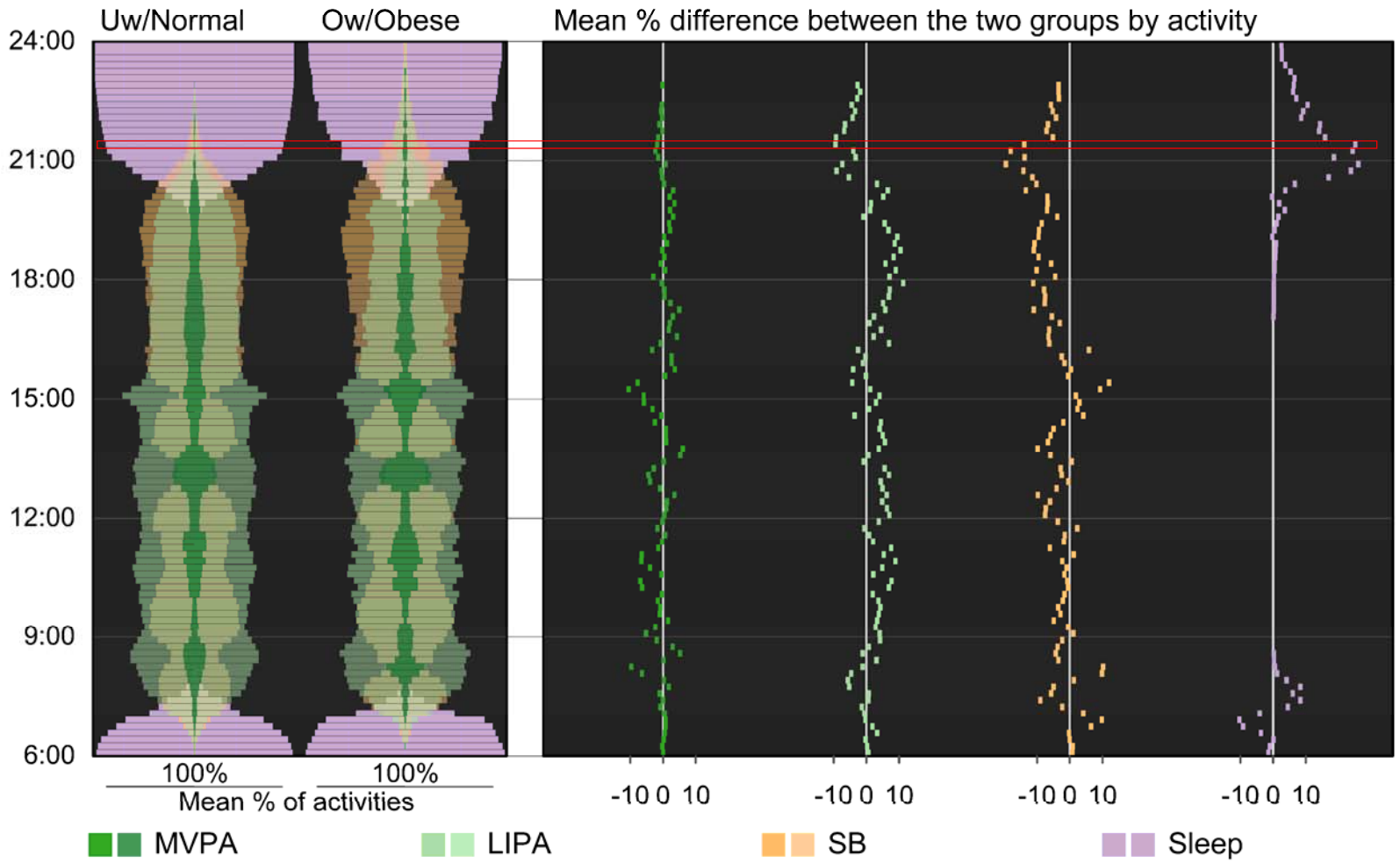


Time-Activity diagram – visualising aggregated patterns at a finer scale

The vertical dimension of the visualisation shows time of day from 6am at the bottom to midnight.

Activities are aggregated at 10 minute intervals.

Activities from 6:00 to 24:00 on weekdays for boys in least deprived areas (Q1) with active travel

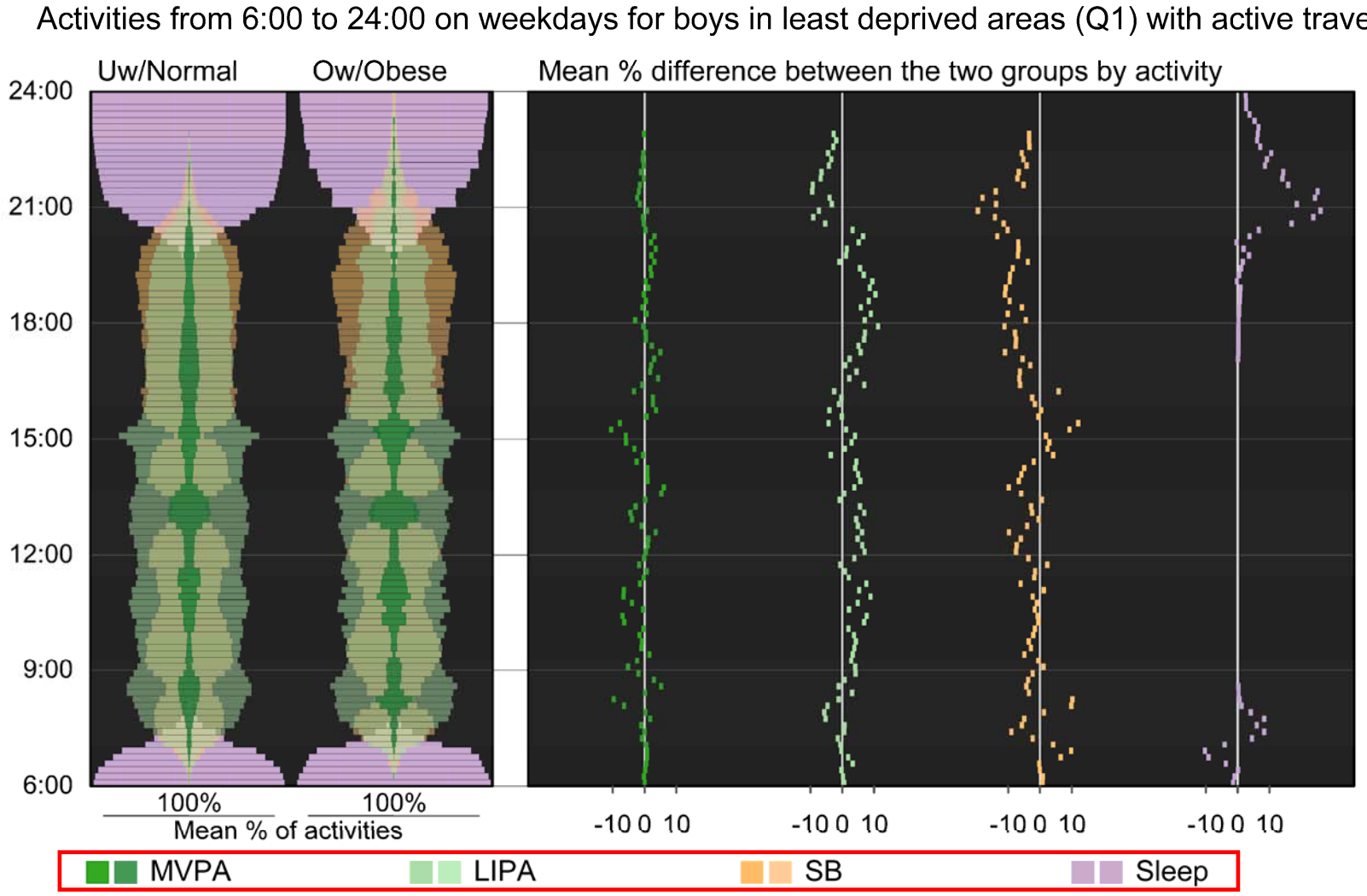


Time-Activity diagram – visualising aggregated patterns at a finer scale

The vertical dimension of the visualisation shows time of day from 6am at the bottom to midnight.

Activities are aggregated at 10 minute intervals.

We use the same colours as before to represent the four activity types: MVPA (dark green), LIPA (light green), SB (orange), and sleep (purple).



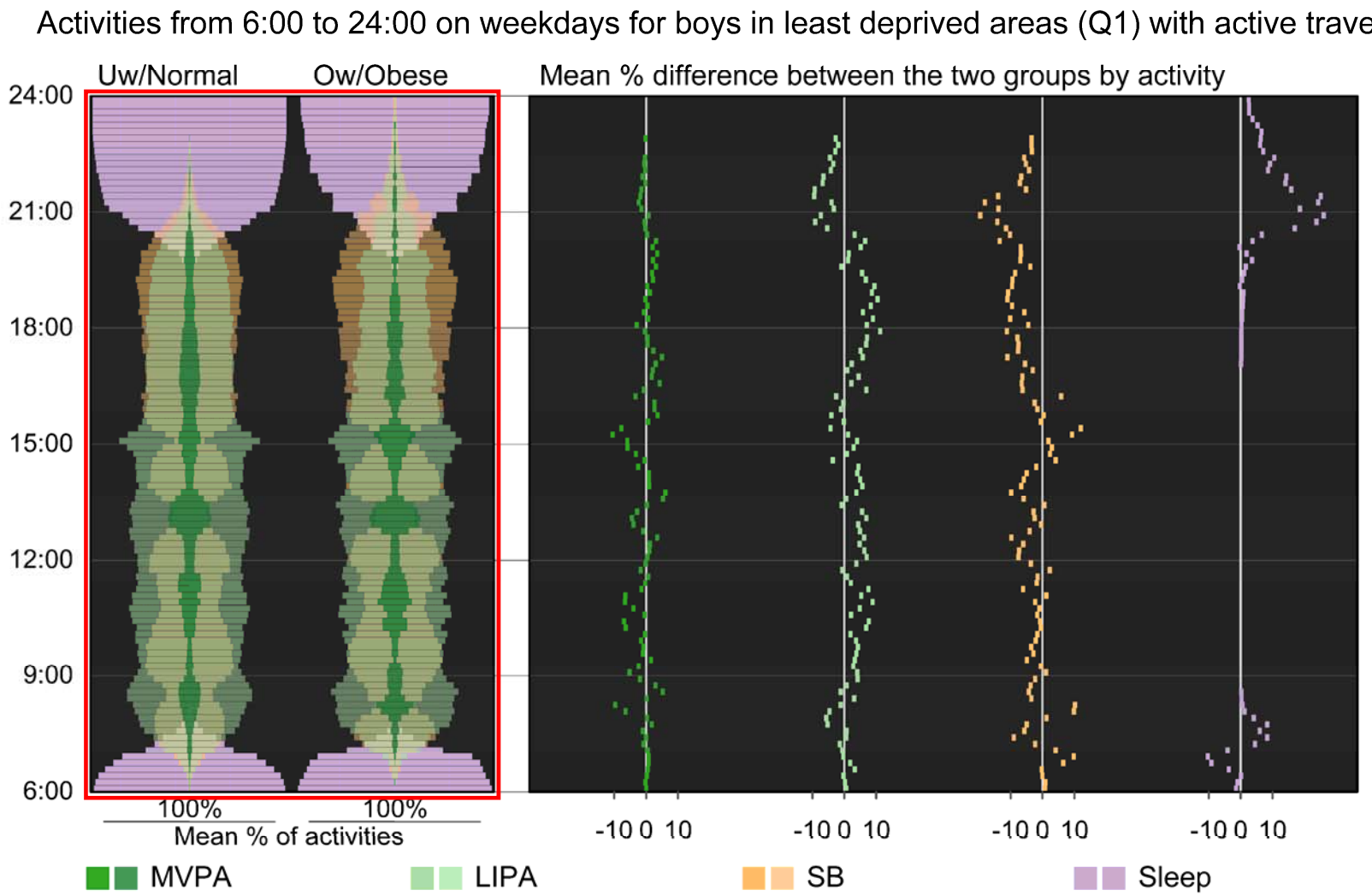
Time-Activity diagram – visualising aggregated patterns at a finer scale

The vertical dimension of the visualisation shows time of day from 6am at the bottom to midnight.

Activities are aggregated at 10 minute intervals.

We use the same colours as before to represent the four activity types: MVPA (dark green), LIPA (light green), SB (orange), and sleep (purple).

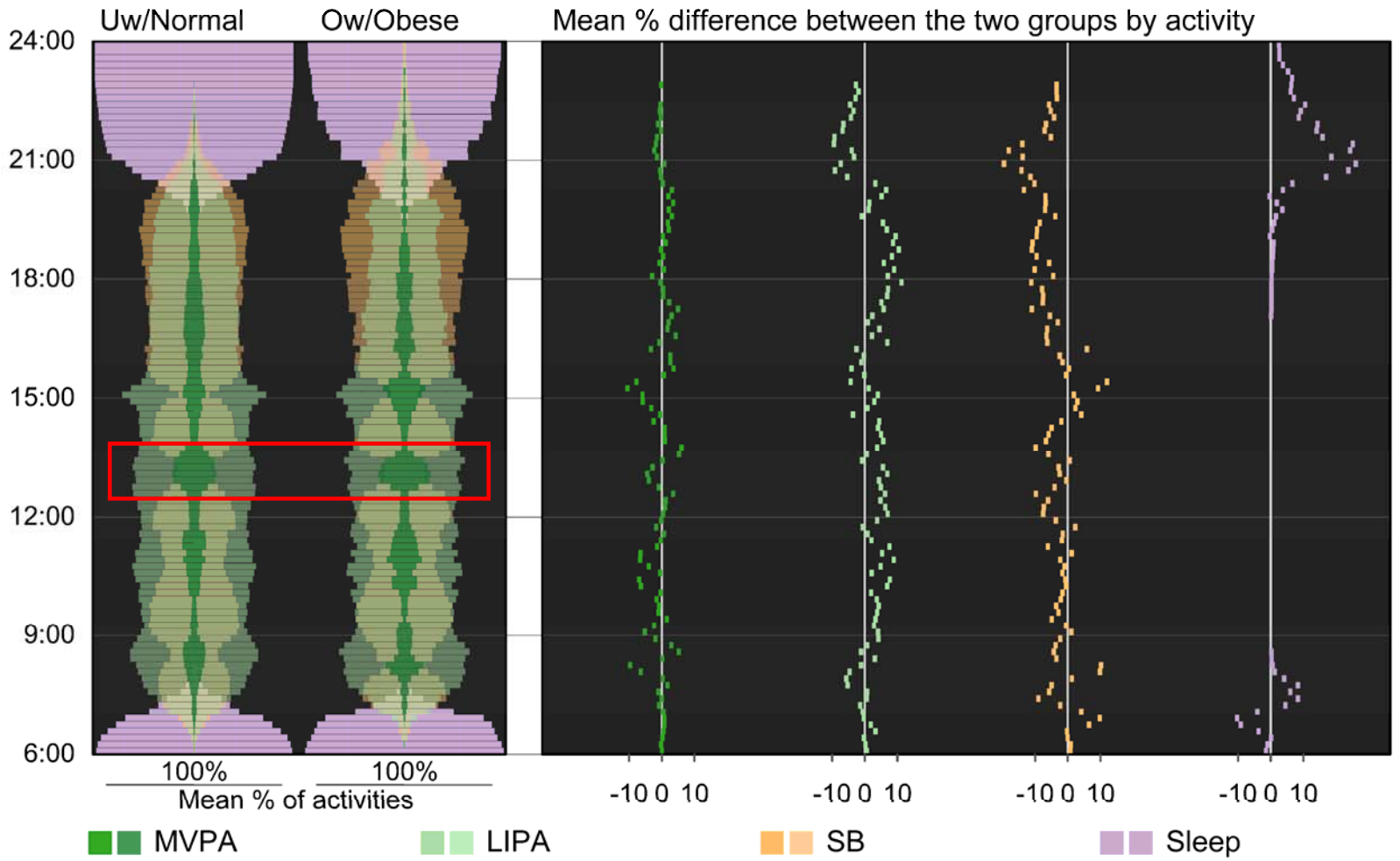
However, the colors are semi-transparent in order to facilitate comparison of different compositional activity patterns.



Time-Activity diagram – visualising aggregated patterns at a finer scale

MVPA was more structured during school hours for all children.

Peaks of MVPA were associated with school break times.



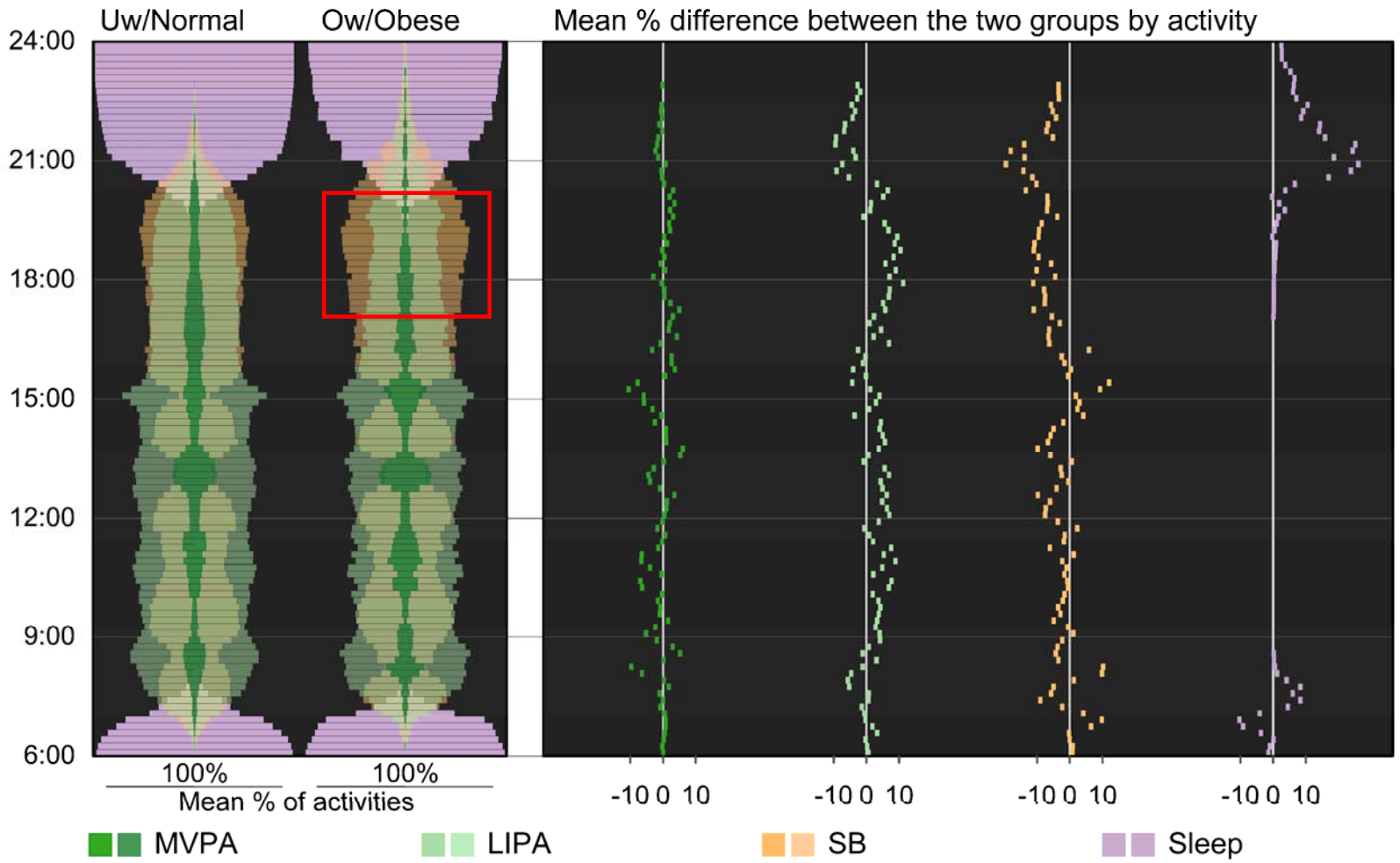
Time-Activity diagram – visualising aggregated patterns at a finer scale

MVPA was more structured during school hours for all children.

Peaks of MVPA were associated with school break times.

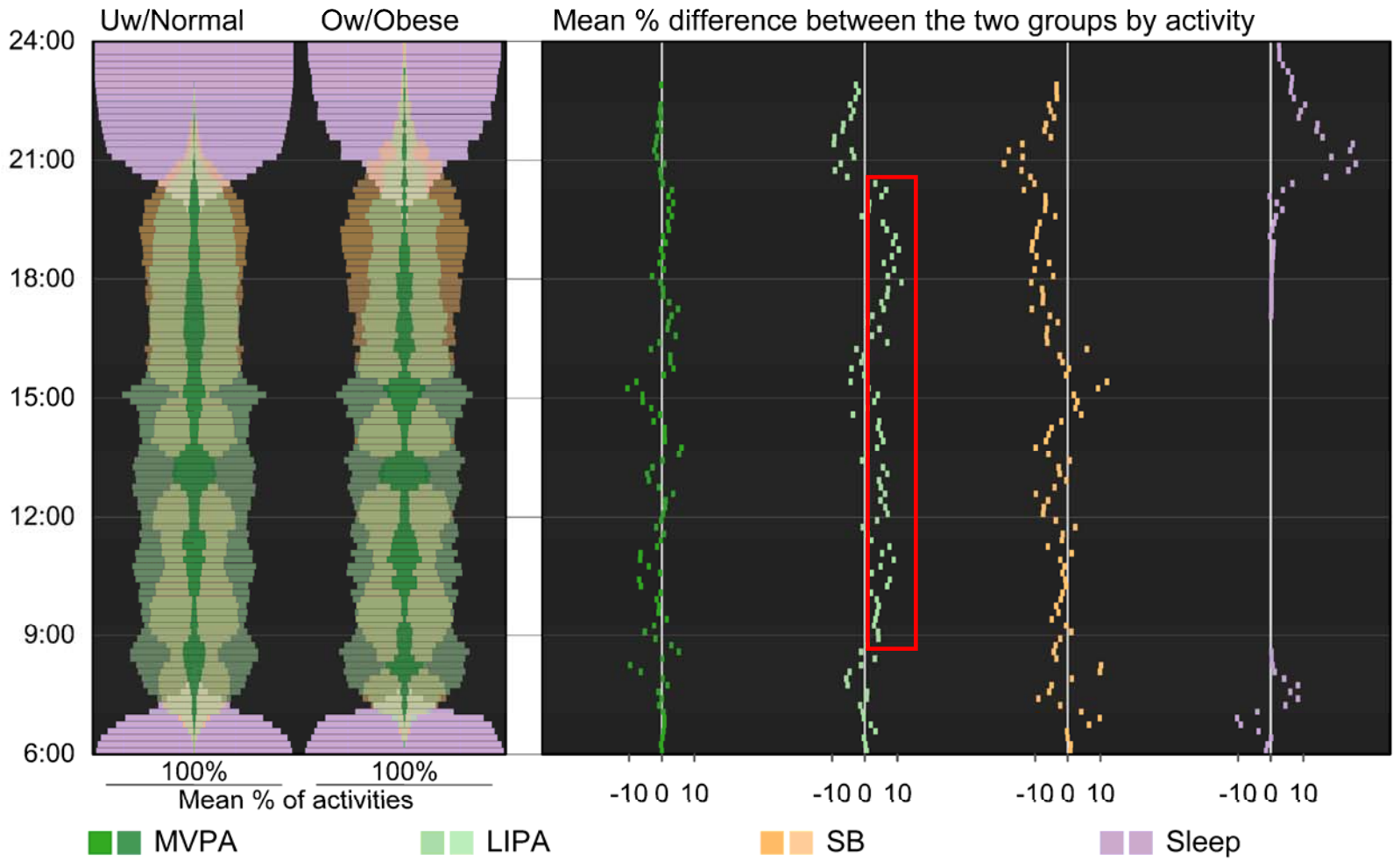
SB dominated time periods between 17:00 and 20:00 for Ow/Obese boys (the orange bandwidth is greater than the other colors).

Activities from 6:00 to 24:00 on weekdays for boys in least deprived areas (Q1) with active travel



Time-Activity diagram – visualising aggregated patterns at a finer scale

Uw/Normal boys spent more time doing LIPA during school hours and early evening.

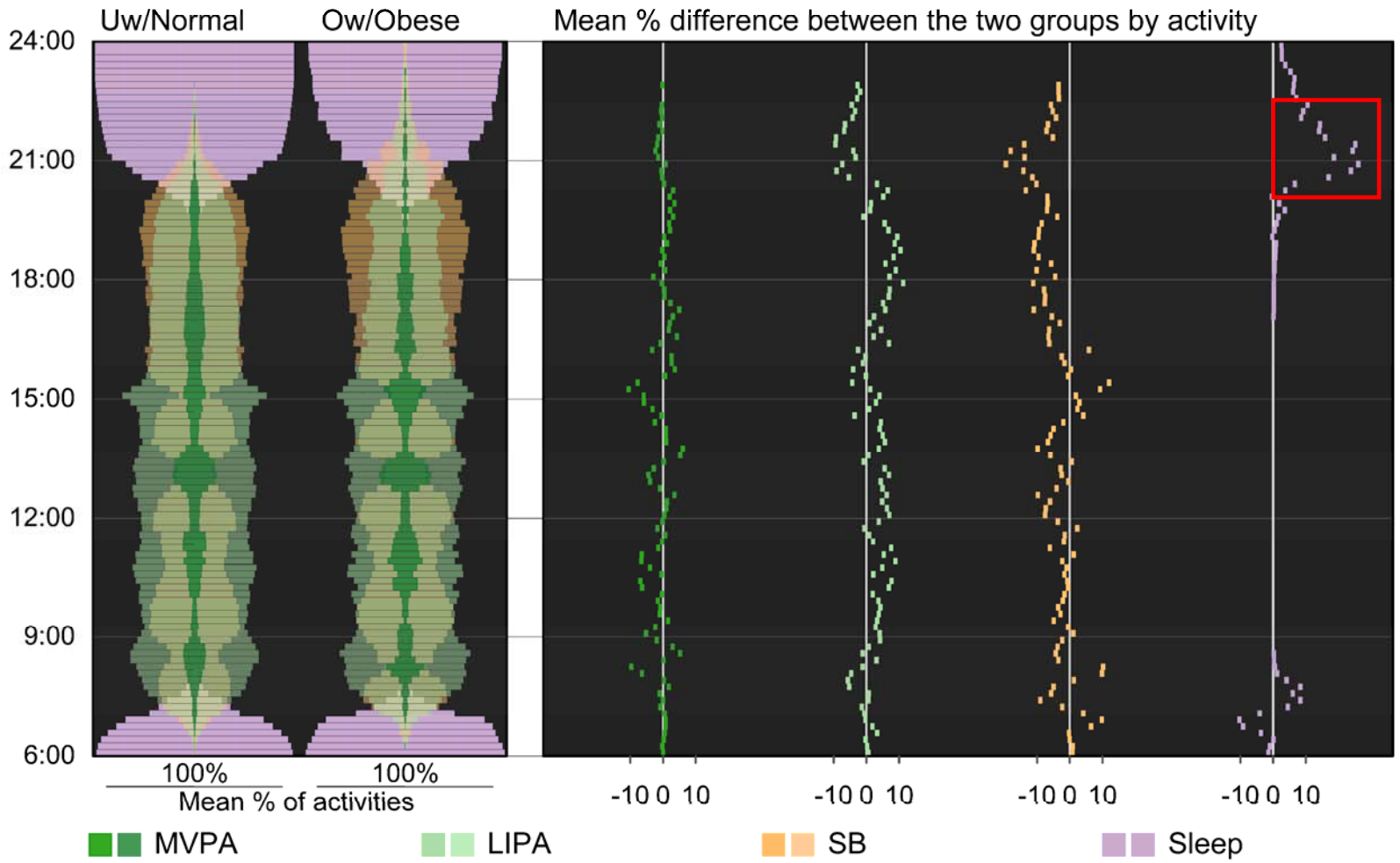


Time-Activity diagram – visualising aggregated patterns at a finer scale

Uw/Normal boys spent more time doing LIPA during school hours and early evening.

They also slept earlier in the evening.

Activities from 6:00 to 24:00 on weekdays for boys in least deprived areas (Q1) with active travel

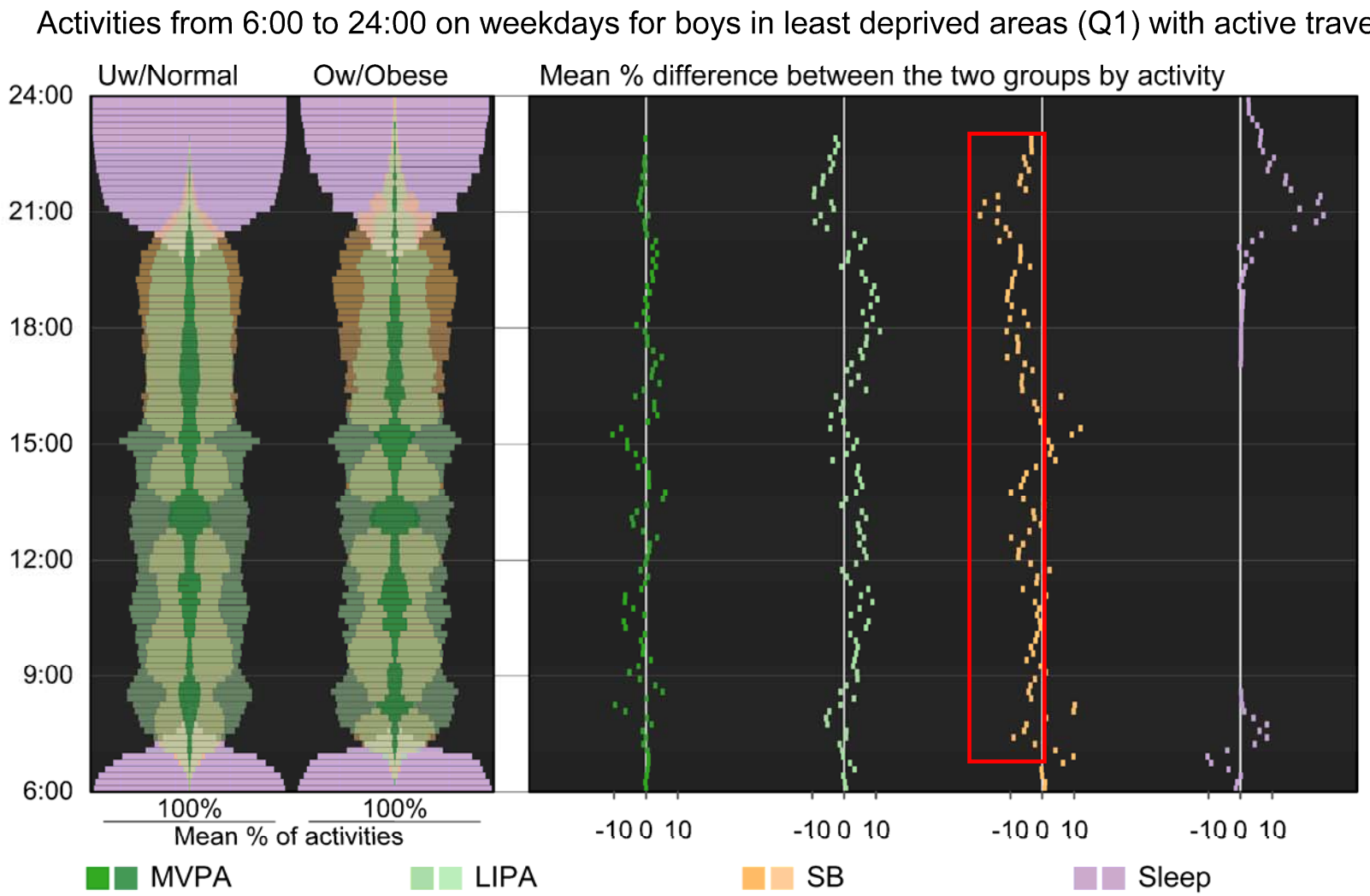


Time-Activity diagram – visualising aggregated patterns at a finer scale

Uw/Normal boys spent more time doing LIPA during school hours and early evening.

They also slept earlier in the evening.

Ow/Obese boys spent more time doing sedentary activities throughout the day.



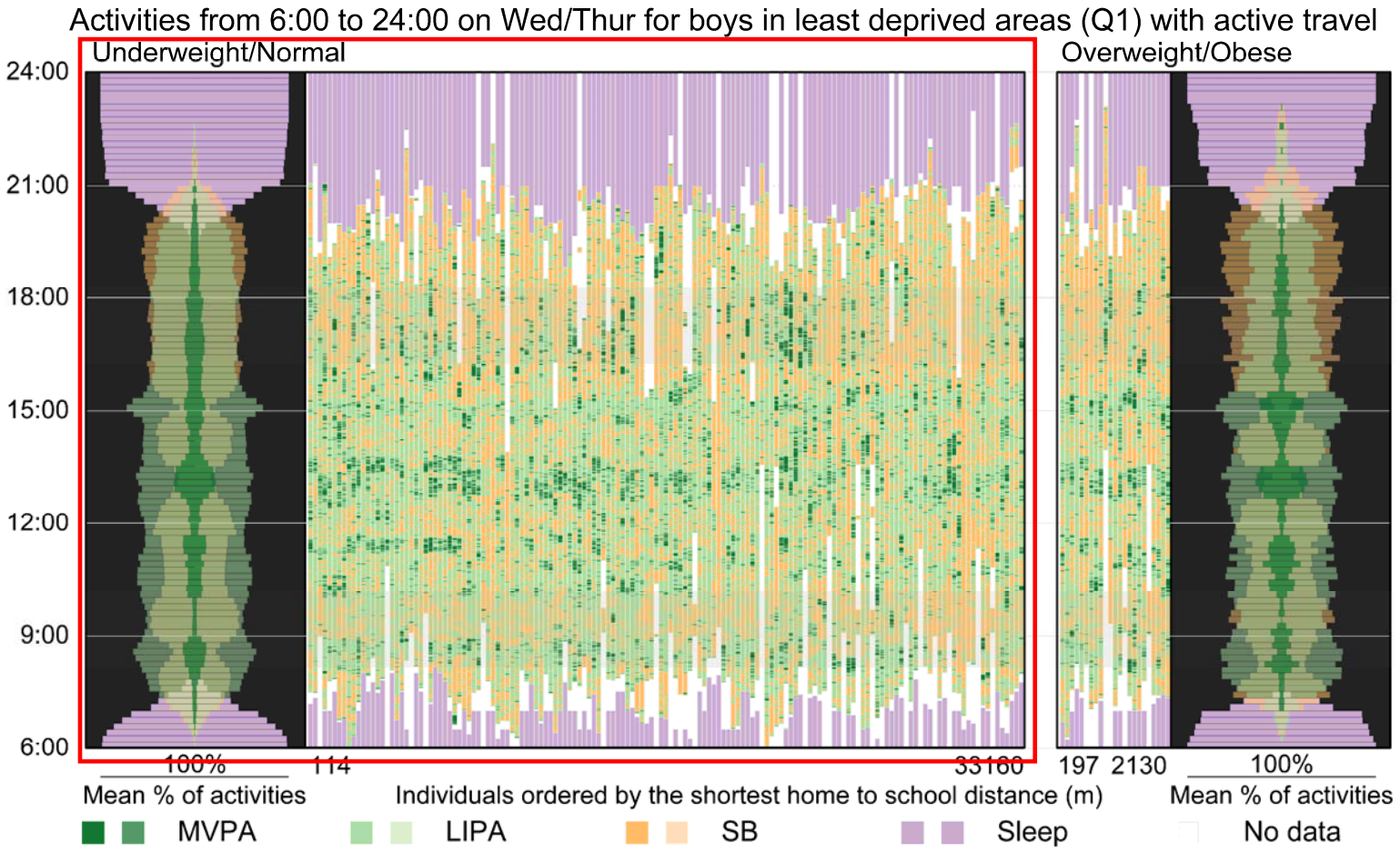
Time-Activity diagram – Visualising patterns at both aggregated and individual scales

This particular time-activity diagram visualises individual, as well as aggregated, patterns.

It shows time use patterns on Wednesday or Thursday for boys in the least deprived (Q1) areas, but only for those with active travel.

The diagram was configured as 2 panels to compare the two groups:

Boys who were underweight or normal are shown in the large panel on the left.



Time-Activity diagram – Visualising patterns at both aggregated and individual scales

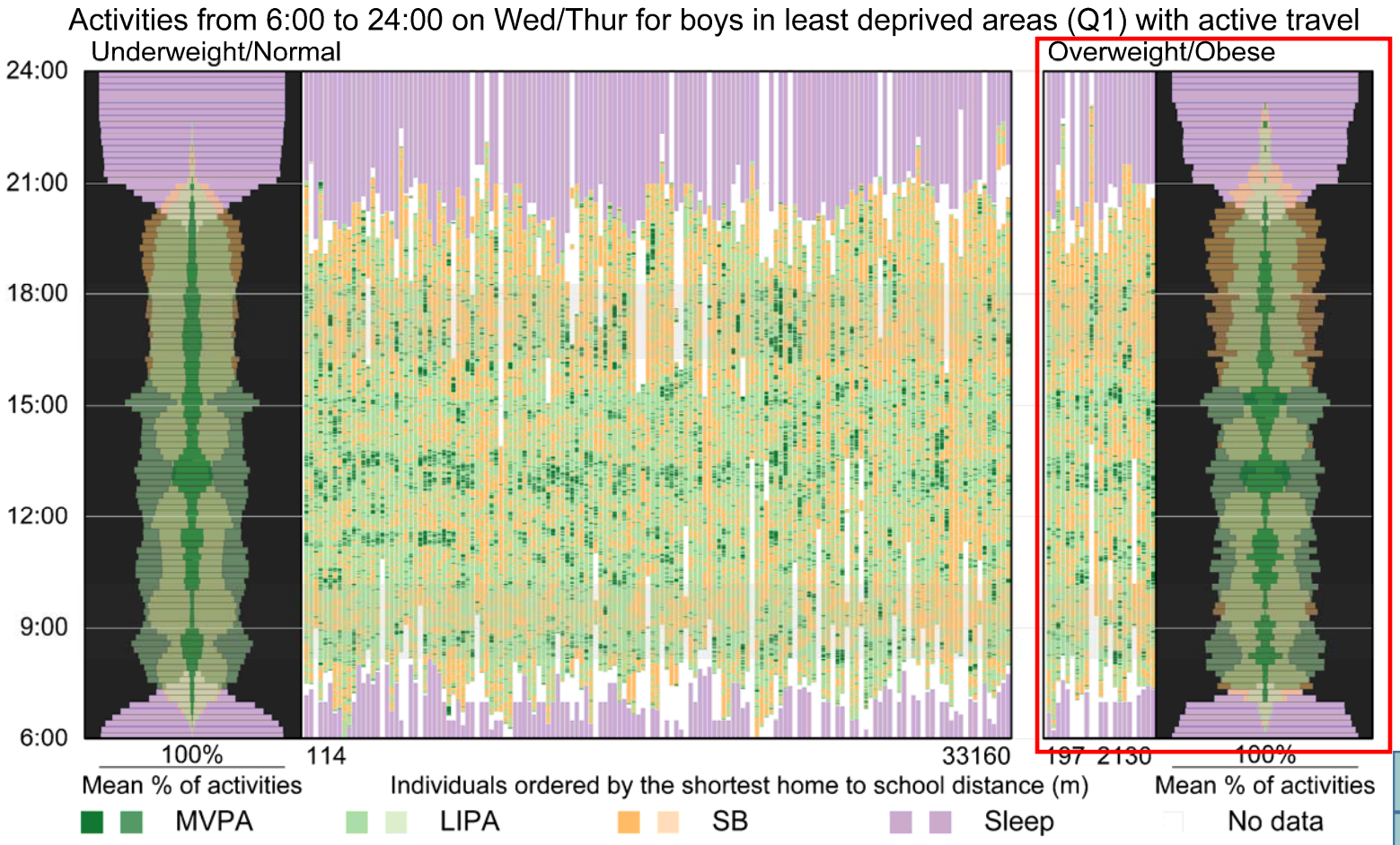
This particular time-activity diagram visualises individual, as well as aggregated, patterns.

It shows time use patterns on Wednesday or Thursday for boys in the least deprived (Q1) areas, but only for those with active travel.

The diagram was configured as 2 panels to compare the two groups:

Boys who were underweight or normal are shown in the large panel on the left.

Boys who were overweight or obese are shown on the right.



Time-Activity diagram – Visualising patterns at both aggregated and individual scales

Individual-level time use patterns for the 4 activity types are shown in the middle of the diagram for these ‘active travel’ boys.

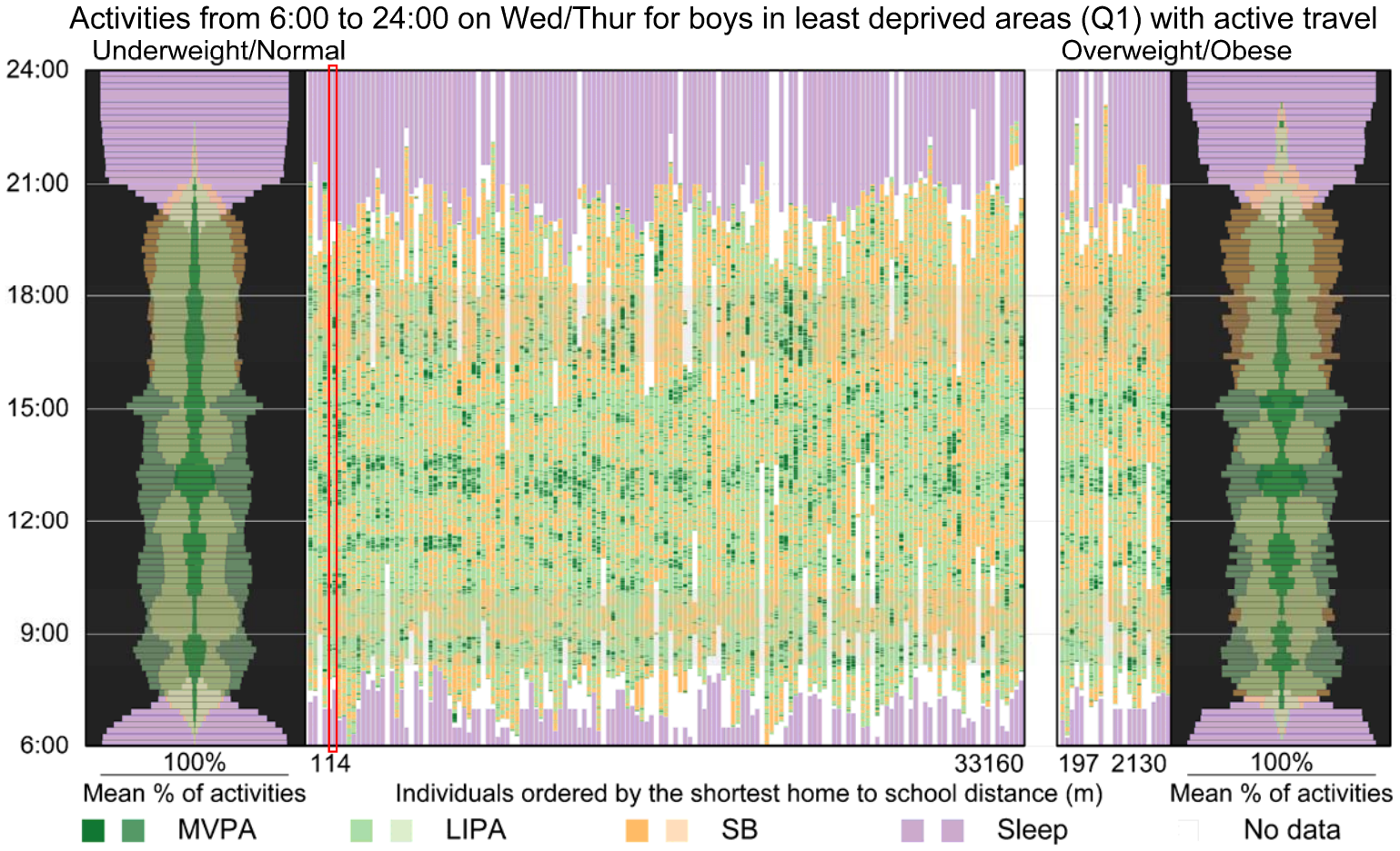
They give us a sense of what the original data looked like.

Time-Activity diagram – Visualising patterns at both aggregated and individual scales

Individual-level time use patterns for the 4 activity types are shown in the middle of the diagram for these ‘active travel’ boys.

They give us a sense of what the original data looked like.

Each vertical timeline represents one boy’s sequential activities on a particular day, in this case a Wednesday or a Thursday, from 6am to midnight.



Time-Activity diagram – Visualising patterns at both aggregated and individual scales

Individual-level time use patterns for the 4 activity types are shown in the middle of the diagram for these ‘active travel’ boys.

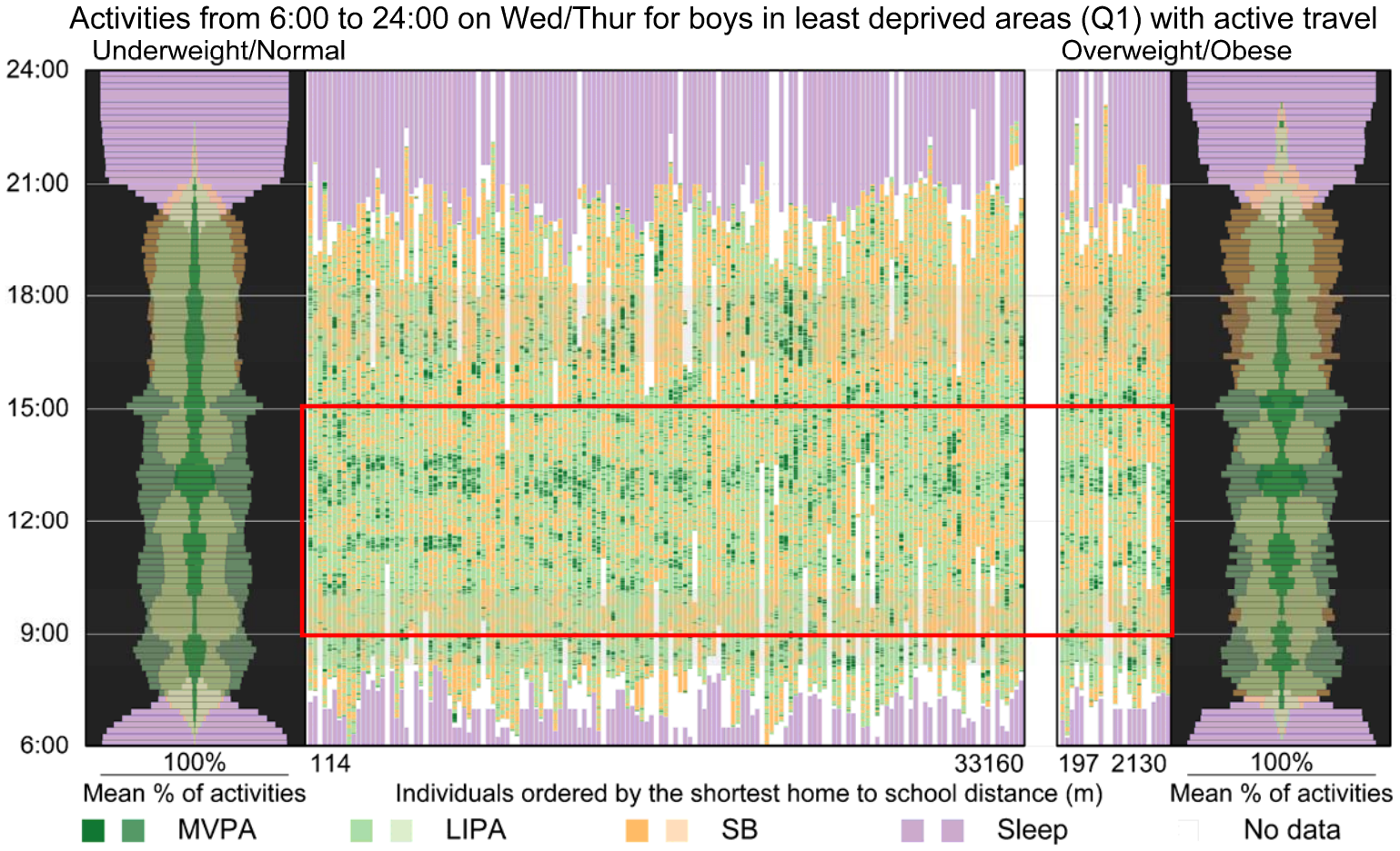
They give us a sense of what the original data looked like.

Each vertical timeline represents one boy’s sequential activities on a particular day, in this case a Wednesday or a Thursday, from 6am to midnight.

The boys’ timelines are ordered within each panel by travel distance (m) from home to school.

Time-Activity diagram – Visualising patterns at both aggregated and individual scales

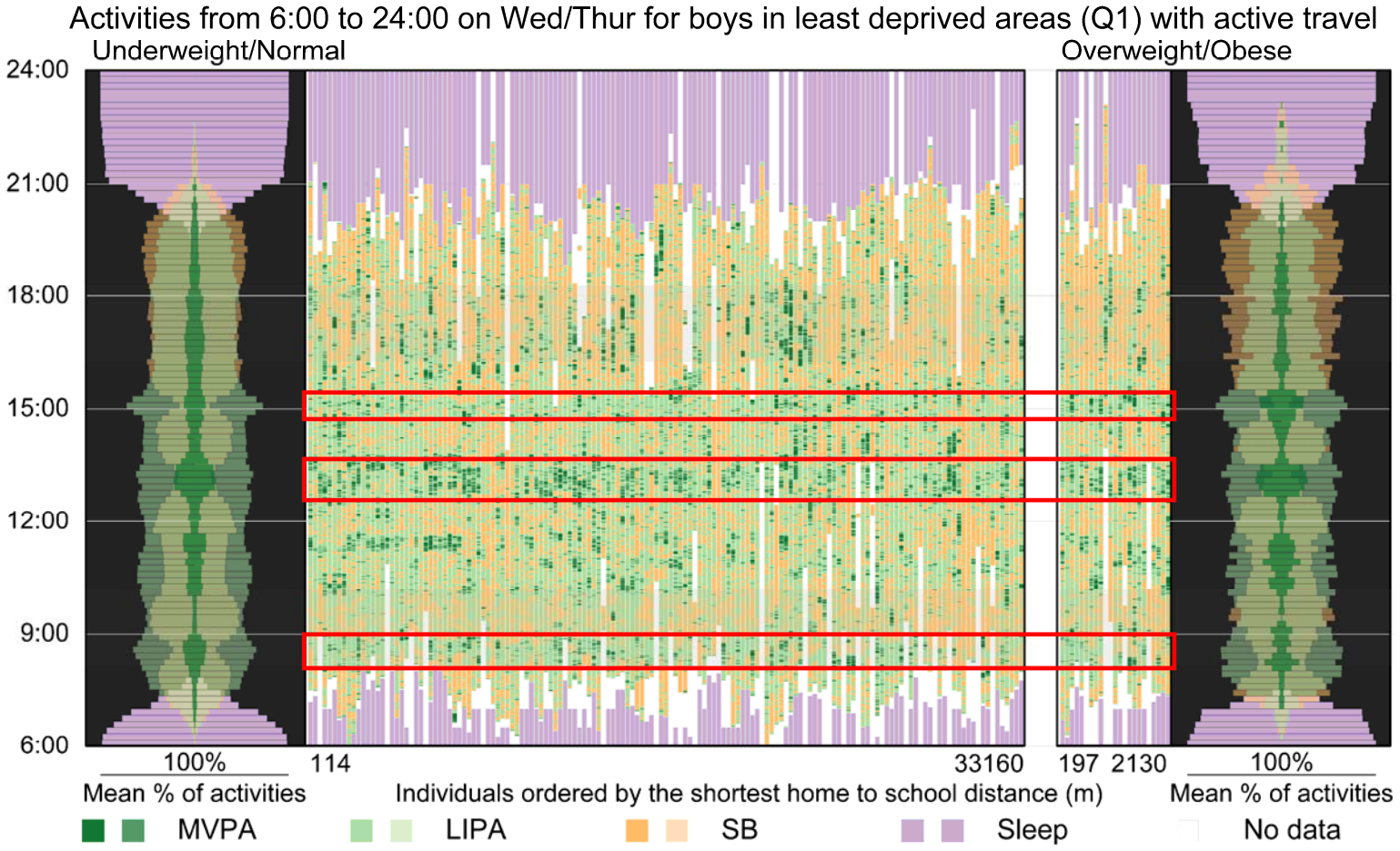
The individual activity patterns show a structure that reflects the structure of the school day for both groups of boys.



Time-Activity diagram – Visualising patterns at both aggregated and individual scales

The individual activity patterns show a structure that reflects the structure of the school day for both groups of boys.

e.g., MVPA and LIPA occur during breaks in the school day and just before and after school.

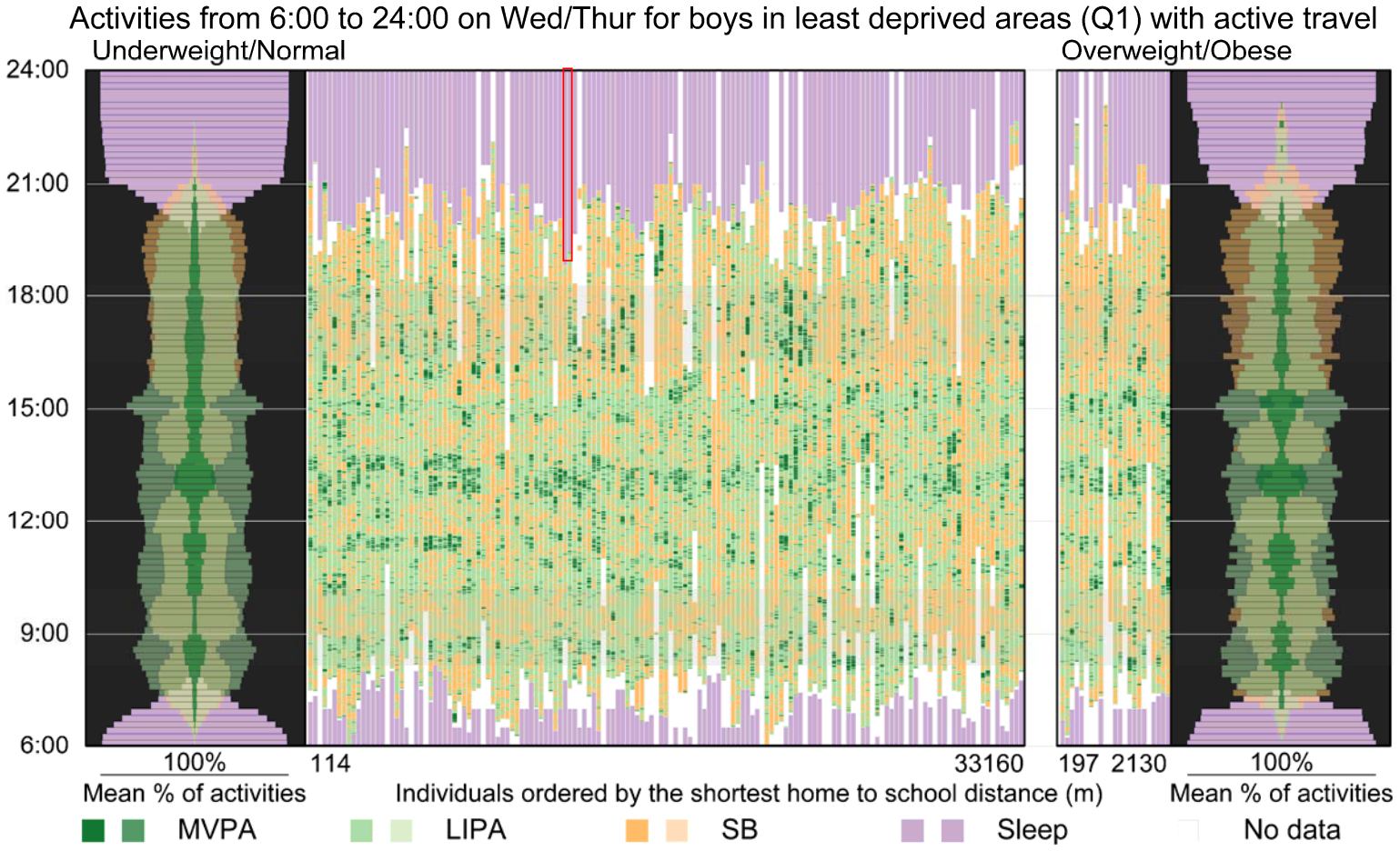


Time-Activity diagram – Visualising patterns at both aggregated and individual scales

The individual activity patterns show a structure that reflects the structure of the school day for both groups of boys.

e.g., MVPA and LIPA occur during breaks in the school day and just before and after school.

Sleeping occurs from as early as 7pm for some of the boys.



Time-Activity diagram – Visualising patterns at both aggregated and individual scales

The individual activity patterns show a structure that reflects the structure of the school day for both groups of boys.

e.g., MVPA and LIPA occur during breaks in the school day and just before and after school.

Sleeping occurs from as early as 7pm for some of the boys.

Aggregated patterns for the two groups (underweight or normal and overweight or obese) are shown on the far left and right.

Conclusions

The focus of this presentation was on demonstrating new visualisation techniques, rather than discovering new knowledge.

We have used ringmaps and time-activity diagrams to visualise children's time use patterns and their association with obesity status, travel mode and neighbourhood context.

The ringmap technique is compact and data driven, an ideal form to represent cyclic time e.g. 24-hour days. It is suitable for representing spatial, temporal and activity information at the population or sub-population level.

Time-activity diagrams present a new way to compositionally visualise and compare activities and linear time at a fine granularity at both the individual and aggregated level using Open Source R software.

Conclusions

Accelerometer data were used to showcase these visualisation techniques, but they can easily be applied to other kinds of data that involve time, space and activity/behaviour, such as time-diary data.

This work is exploratory. Your feedback and comments will be greatly appreciated.

We would welcome any potential collaboration opportunities, .e.g. to visualise other kinds of data.

Thank you for your attention

Zhao, Jinfeng; Mavoa, Suzanne; Chang, Kevin; Mackay, Lisa; Stewart, Tom, Ikeda, Erika; Donnellan, Niamh; Smith, Melody

jinfeng.zhao@auckland.ac.nz

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

MEDICAL AND HEALTH SCIENCES