What are the Biomechanical Features of Clinically Relevant Movements during Sleep?

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Summary
Movement during sleep can cause disruptions that reduce sleep quality, but clinical criteria focus solely on periodic limb movements (PLMs) associated with restless leg syndrome. The goal of this research is to motivate a data-driven understanding movement and the resulting implications for sleep health. Pilot analysis of movements observed during sleep identified significant muscle activity undefined by current clinical guidelines. Preliminary analysis found that the undefined movements share features with movements (PLMs) that have been deemed clinically relevant. This forms the basis to explore what makes a movement clinically relevant and to determine if certain movements have been overlooked.

Introduction
Movement plays a vital role in enabling us to interact with our surroundings when awake, but movement is commonly viewed as a hinderance to sleep, with poor sleep often colloquially described as "tossing and turning". Despite this affiliation, the American Academy of Sleep Medicine (AASM) Scoring Manual only defines repetitive activity in PLMs, a hallmark of restless leg syndrome [1], as clinically relevant. However, clinical observations have noted the relevance of non-PLM movements for sleep quality [2,3]. This has led to a push to establish further criteria to describe non-PLM movements and their clinical implications [2,3]. The need for such diagnostic criteria is especially important for children, as sleep is essential for physical growth and mental development [2]. This present work explores the different movements during sleep to motivate a data-driven approach to understand their associations with sleep quality.

Methods
We analyzed data from a routine clinical polysomnography assessment of a 12-year-old boy out of a dataset containing over 3000 sleep studies from the Sleep Lab at BC Children's Hospital. We focused on EMG recorded at 256Hz as part of the Embla Sandman Elite Polysomnography System. EMG electrodes were placed on each of the participant's legs to obtain a differential EMG signal capturing movements of both legs. Polysomnography data were reviewed and annotated according to AASM Scoring Manual Version 3, noting any instances of clinical interest including PLMs (a series of >3 movements within a period of 5-90 seconds between movement onset) and arousals (increased activity from EEG).

To explore general leg movements, EMG data were extracted and filtered using a 4th-order Butterworth lag-less bandpass filter (10-120Hz); rectified; and filtered using a 4th-order Butterworth lag-less low-pass (2Hz) to obtain the EMG envelope. Using the envelope, we extracted instances of movement defined by AASM as an increase of 8 mV above the baseline that remained above 2 mV for at least 0.5 seconds. Any movement that occurred within 0.5 seconds of another was considered as a single movement. Movements extracted from EMG were associated with clinical labels such as arousal, wake, and PLM.

Results and Discussion
EMG analysis identified a total of 430 individual movements. Broken down into the associated clinical labels, 284 corresponded to wake periods, 78 corresponded with arousals (often associated with a breathing disturbance), 34 corresponded to a PLM associated with an arousal, and 34 were not associated with any clinical labels. Of the 34 movements not associated with any clinical labels, the clinical team identified 14 as a significant non-clinical "movement". Across labels, observed movements shared similar peak magnitude and duration. This poses the question of what features distinguish clinically relevant movements from those which have not been determined clinically relevant.

Conclusions
We observed significant movement during sleep. While many movements were associated with clinical labels (such as arousals), several that were not associated with clinical labels shared features with those that were. This motivates further data-driven exploration of the larger dataset to uncover what makes a movement clinically relevant for sleep.

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References
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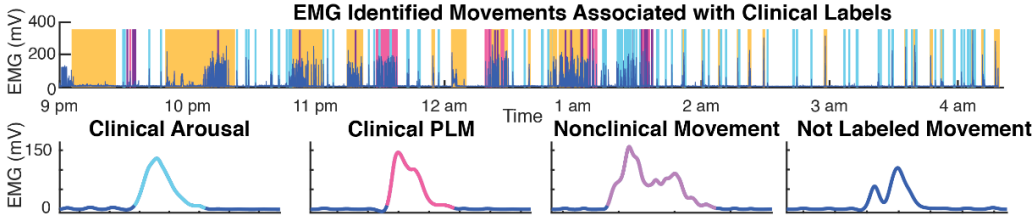

Figure 1: EMG data from a single polysomnography with AASM clinical annotations. The example non-clinical movement had similar characteristics (peak envelope) to movements associated with clinical labels, highlighting the need to define and explore their clinical relevance.