Duration and patterns of habitual physical activity in adolescents and young adults with cerebral palsy

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ABBREVIATION
HPA Habitual physical activity
GMFCS Gross Motor Function Classification System

AIM Adolescents and young adults with cerebral palsy (CP) show reduced motor function and gait efficiency, and lower levels of habitual physical activity (HPA), than adolescents with typical development and children with CP. This study examined activity duration and patterns in this population in the Middle East through long-term monitoring of a large sample using accelerometers.

METHOD Adolescents and young adults with bilateral CP at Gross Motor Function Classification System (GMFCS) levels II, III, and IV, were monitored in their habitual environment for four consecutive days with ActivPAL3 monitors. Time spent in sedentary, standing, and walking activities, and frequency of walking steps and transitions, were analysed for each GMFCS level.

RESULTS Measurements were made on 222 participants (132 males, 90 females; mean age 16y 9mo SD 2y, range 13y 4mo–22y). The Mann–Whitney U test demonstrated significant differences (p < 0.05) between GMFCS levels, showing reduced walking and standing activity and increased sedentary duration at higher GMFCS levels (p < 0.001), except for increased standing time between GMFCS levels II and III (p = 0.07). Participants in educational facilities exhibited less sedentary behaviour than those who were homebound (p < 0.05).

INTERPRETATION These descriptions of duration and frequency of active and sedentary behaviours may serve as a basis for recommendations to minimize inactivity in this population. Adolescents and young adults with CP in the Middle East demonstrate similar patterns of HPA to their peers in other regions.

Habitual physical activity (HPA) may be defined as the magnitude and pattern of body movements during the usual activities of daily living, including sleep and rest, work, and leisure. Sedentary behaviour refers to activities that increase energy expenditure above the resting level by less than 50% and includes activities such as sleeping, sitting, lying down, and watching screen-based entertainment.1,2 Regular and intensive physical activity, even in individuals with disabilities, is directly associated with physical fitness, improved quality of life, and psychological functions;3 low levels of activity contribute to the risk of chronic cardiovascular disease4 and other health issues.5

Adolescents and young adults with cerebral palsy (CP) face many difficulties with functional mobility in their transitional growth stages because, during adolescence, gross motor function capacity and gait efficiency decline.6 Additionally, adolescents with CP face a discontinuity of care; as paediatric rehabilitation ends and they do not qualify for paediatric services there are few adult rehabilitation services available to meet their health needs.7 Compared with younger children with CP, adolescents and young adults with CP exhibit lower levels of physical activity, less walking activity, and more sedentary behaviour;8 and their activity decreases as gross motor function deteriorates.8,9 Adolescents and young adults are less physically active than their peers with typical development, although sedentary behaviour may not be very dissimilar, because fewer structured activity programmes are available to them and because of the physical activity restrictions and comorbidities associated with CP.8,10

Habitual physical activity patterns can now be monitored over hours and days in normal daily living conditions because of the development of accelerometer-based monitors. These monitors are affordable, simple to operate, small and lightweight, and ideally suitable for long-term monitoring of HPA.11 In addition to counting steps, like pedometers, accelerometers respond to the magnitude of movement and inclination of monitored body segments, identifying different postures and creating a more detailed profile of the wearer’s HPA.12,13 The ActivPAL3 (PAL
Technologies, Glasgow, UK) monitor does not require the user to be in a fully vertical position in order to classify the position as standing or identify a transition. One study validated the ActivPAL in children with hemiplegic CP at Gross Motor Function Classification System (GMFCS) levels I, II, and III and concluded that it was capable of measuring the number of steps and the time spent walking for the less complex hemiplegic gait patterns.\(^1\)\(^4\)

There is growing evidence that event-based analysis of HPA, in addition to analysis of total HPA, may provide important information regarding physical activity patterns. When the time and duration of sequences of physical activity and sedentary patterns are examined, it is clear that much activity occurs in short bursts at certain times of the day, and that short activity periods are separated by long periods of inactivity. The analysis of activity events (walking, standing, transitions, and sedentary behaviour) and their temporal patterns can add additional information regarding mobility status. These patterns of physical activity and sedentary behaviour may be related to risk factors for disease\(^1\)\(^1\)\(^5\)\(^1\)\(^5\)\(^1\)\(^6\) and adjustments may be recommended to reduce inactivity. Obeid et al.\(^1\)\(^6\) reported that children and adolescents with CP and peers with typical development demonstrated different patterns of sedentary behaviour. Therefore, it seems important to describe in detail the activities and patterns of a population of adolescents and young adults with CP.

The primary aim of this study was to document HPA in adolescents and young adults with CP based on accelerometer analyses, in terms of the duration and frequency of sedentary behaviour and active events in normal daily living, as well as to compare the number and frequency of these events in individuals with different levels of mobility dysfunction. This detailed long-term monitoring may provide useful descriptions regarding sedentary behaviour and the function and activity level of the participant.\(^1\)\(^7\) A secondary aim was to document the long-term HPA of adolescents and young adults with CP in Jordan, Israel, and Palestine, and also to compare individuals in educational institutions with those who were homebound. A description of the HPA levels of this population will enable comparison with peers in other, mainly developed, countries. This information may assist and encourage authorities in the Middle East to invest in facilities and education to promote a more physically active lifestyle for these individuals.

**METHOD**

**Participants**

Participants were recruited from clinical centres and schools through telephone and personal interviews conducted by the researchers in each centre in Israel, Jordan, and Palestine. Adolescents and young adults with CP were included in the study if they met the following criteria: (1) diagnosis of bilateral (diplegia, quadriplegia) spastic/mixed-type CP; (2) age from 13 to 22 years; (3) GMFCS\(^1\)\(^8\) at level II, III, or IV (see GMFCS levels defined below), classified with their usual shoes, orthotics, and assistive mobility devices; (4) cognitive level sufficient to comprehend and cooperate with measurements; and (5) no orthopaedic surgery or other spasticity management within the previous 6 months. Participants were excluded if they had (1) progressive degenerative condition of the central nervous or musculoskeletal system, (2) experienced an injury of the lower extremity (reported fracture, sprain, or strain) within the previous 6 months, or (3) experienced exercise-induced asthma, cardiac problems, or uncontrolled seizure disorders.

Ethics approval for this study was granted by ethical review boards of the three participating centres: Assaf-Harofeh Medical Center, the Basma Center for Disabled Children, and Jordan University of Science and Technology. Written informed consent to participate in the study was obtained from participants or their parents/guardians after a detailed explanation of the study.

**Procedures**

Researchers from the participating centres conducted joint training workshops on the use and placement of accelerometers and the method of downloading and sending data to the Department of Biomedical Engineering at Ben-Gurion University of the Negev. The researchers and paediatric physical therapists who classified participants at particular GMFCS levels had at least 7 years’ experience of working with children and adolescents with CP.

Demographic and anthropometric characteristics (weight, height, and calculated body mass index) were noted and a socio-economic questionnaire was completed by interview with the participant and parent or guardian. The questionnaire pertained to the education level of the participant and each parent, income level and occupation of family members, number of people living in the home, type of home (private residence, apartment floor level, village/town/city), and accessibility to home/school/work (stairs, elevator, and transportation type). The parents/guardians and participants were given verbal and written instructions and a demonstration of the placement of the monitor.

The participants came for one visit to the laboratory, where they received specific instructions and the monitor was placed on the appropriate body site. The participants’ activity was monitored for a period of approximately 96 continuous hours in their habitual environment. The majority of the records included two weekend days, but on occasion consisted of four weekdays only when monitors

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**What this article adds**

- Event-based analysis is used to give insight into habitual physical activity in adolescents with CP.
- Higher GMFCS levels are associated with a reduction in the number and increase in the duration of sedentary behaviour events.
- The habitual physical activity of Middle East adolescents with CP is the same as found in other regions.
- Participants with CP in educational facilities exhibited less sedentary behaviour than those who were homebound.
or personnel were not available at weekends. On several occasions the monitoring was repeated because the ActivPAL had not been placed in the correct position. Participants were asked to wear the monitor on their less affected leg for the whole period, except when bathing and swimming. They were asked to maintain a structured daily diary describing their general activity and unusual events to validate adherence to the instructions and to explain problematic events data.

**Measurements**

The GMFCS level was determined using the GMFCS—Expanded and Revised version (GMFCS-ER). The GMFCS for CP is based on self-initiated movement, with emphasis on sitting, transfers, and mobility. The GMFCS-ER includes an age band for adolescents aged 12 to 18 years. The focus of the GMFCS is on determining which level best represents the child or adolescent’s present abilities and limitations in gross motor function. Emphasis is on usual performance in home, school, and community settings, that is what they do rather than what they are capable of doing. The GMFCS levels of mobility are as follows: I – walks without limitations; II – walks with limitations; III – walks using a hand-held mobility device; IV – self-mobility with limitations, may use powered mobility; V – transported in a manual wheelchair.

Physical activity was recorded using an ActivPAL3 triaxial accelerometer-based activity monitor. It is a small device (15g, 3.5 × 5.3 × 0.7cm), placed on the midline of the anterior aspect of the thigh, attached using a nitrile sleeve and conformable dressing. The capacitive accelerometer responds to gravitational acceleration, indicating the posture of the wearer (horizontal or upright), and to acceleration as a result of movement of the thigh, indicating walking activity. The validity of ActivPAL has been demonstrated for healthy adults, children and adolescents, and children with CP.

Adolescents at GMFCS level IV mostly use wheelchairs. However, about 25% transfer themselves using a walker or furniture in their home environment. Wheelchair mobility in this study was considered to be sedentary. In this group we placed the accelerometer on the participants’ thigh, exactly as done with the other participants.

**Data analysis**

Mean duration and frequency of bouts of activity were calculated for each participant. Short consecutive bouts of walking (corresponding to a single step) were accumulated and represented as a single walking event. There is no conclusive definition of the maximal duration of a standing event that can be considered a short pause in an ongoing walking event. Chastin et al. chose a maximal duration of 10 seconds, which is consistent with the ActivPAL default value for the minimal duration of a standing event. Sellers et al. suggested a threshold of 30 seconds. With these considerations, a threshold of 20 seconds was chosen for this study. Therefore, standing events disrupting a continuous walking event, and lasting 20 seconds or less, were coded as walking and considered part of a walking event.

The acceleration data were downloaded to a computer, where they were processed with ActivPAL3 software, providing activity measures such as time spent in sedentary activity (sitting or lying down), standing, and walking, step frequency, and the number of bouts of activity (events). These results were analysed using MATLAB (Mathworks) and Prism (GraphPad).

Participants were divided according to three GMFCS levels (II, III, and IV) and analyses consisted of within- and between-group comparisons. A non-parametric outlier test (based on Chebyshev’s theorem) was conducted for each GMFCS level in order to identify conspicuous results in every measured activity. In this test, an outlier value is more than 4SD from the mean, allowing a wide range for the natural diversity of the population.

The distributions of the results were significantly skewed, making assumptions of a normal distribution invalid. Therefore, the Mann–Whitney U non-parametric test was applied for testing differences between groups. This test is based on the median of the data set. However, because many studies have presented means and SD for activities, these are also presented for comparison with other studies. Statistical significance was determined as p<0.05.

**RESULTS**

A total of 429 adolescents and young adults were approached. Of these, 107 did not meet the inclusion criteria and 88 were not interested. Data from 10 were outliers and removed from the data set and data from two were lost. The analysed activity data was obtained from 222 participants (132 males, 90 females; mean age 16y 9mo SD 2y, range 13y 4mo–22y). Their age, anthropometric, and disability characteristics are listed in Table I.

The HPA measures for an average recording duration of 4 days (SD 5h) are shown as a percentage per 24 hours in Table II. Significant differences (p<0.001) between all GMFCS levels were found for each of the three activity durations, except for standing time between GMFCS II and III (p=0.07). As expected, in participants with higher GMFCS levels (lower motor function), sedentary duration was significantly longer and durations of standing and walking were shorter. Such participants also took fewer steps per day, and had fewer transitions from standing to walking. These results confirm the expected inverse relationship between GMFCS level and physical activity.

The median duration and frequency of each event bout per 24 hours are presented in Figure. 1. The number of sedentary, standing, and walking events decreased as GMFCS level increased. For GMFCS level IV, the duration of each sedentary event was highest, at a median of 100 minutes, while the walking events were the shortest, at approximately 16 seconds. The duration of each standing event was not significantly different between GMFCS levels II and IV, at about 49 seconds. The distributions of the
durations of sedentary and walking events for different levels of GMFCS are shown in Figure 2. The plots show that 50% of the sedentary events are shortest for GMFCS level II, and longest for GMFCS level IV. Conversely, walking events are longest for GMFCS level II and shortest at GMFCS level IV.

The difference in HPA between participants who attend educational institutions (students) and those who remained at home was also tested as above at each GMFCS level. There were significant differences in HPA between student and homebound participants only among participants at GMFCS level III; no significant differences between these two categories were found at GMFCS levels II and IV. However, when data for participants at all three levels were combined, the students were more active, spending significantly less time being sedentary and more time walking, and taking more steps ($p<0.05$), than those who remained at home.

**DISCUSSION**

To our knowledge, this is the first study to present a detailed analysis of HPA levels and patterns in adolescents and young adults with CP in terms of the bouts of activities investigated (sedentary, standing, walking duration, walking steps, and transitions), and including GMFCS levels III and IV as separate groups. This study also describes the daily HPA of adolescents and young adults with CP in the Middle East. As expected, those who were more disabled were less physically active during the day, being more sedentary, spending less time standing, and walking with fewer transitions. Additionally, this study suggests that educational facilities benefit students with CP by decreasing sedentary behaviour compared with homebound participants.

These results generally agree with findings of studies of similar populations in Australia, Canada, and the USA. Björnson et al., using a Step Watch monitor, reported an average number of 8400 daily steps among 81 adolescents with CP (GMFCS levels I, II, and III), aged 10 to 13 years, in the USA, compared with an average of 13 400 steps in an age-matched group with typical development. Although the average number of steps taken by adolescents with CP is higher than that found here (6282 steps per 24 hours in those classified as GMFCS level II), this can be accounted for by the younger population sample in the USA study (mean age 11.8y) and the fact that 38% of participants in that study were classified as GMFCS level I. Stevens et al. reported a lower and more similar number of 6342 steps per day among 27 children and adolescents (age range 4–18y) with CP and GMFCS levels I and II from the USA. Tang et al., using the ActivPAL monitor, measured an average of 6659 daily steps in five participants with CP (GMFCS levels not stated) aged 14 to 17 years. Recently, the HPA of adults with CP from the Netherlands, average age 36 years, was reported using the Activity Monitor (AM-TEMEC Instruments BV, Kerkrade, The Hague).

**Table I: Participant characteristics ($n=222$)**

<table>
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<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
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</thead>
<tbody>
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<td>Age, y:mo</td>
<td>16:9</td>
<td>2.0</td>
<td>13y:4–22:0</td>
</tr>
<tr>
<td>Height, cm</td>
<td>155</td>
<td>10</td>
<td>125–180</td>
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<tr>
<td>Weight, kg</td>
<td>52.6</td>
<td>11.9</td>
<td>24.0–86.0</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>90</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>132</td>
<td>59</td>
<td></td>
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<td>GMFCS level</td>
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<tr>
<td>II</td>
<td>137</td>
<td>62</td>
<td></td>
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<td>III</td>
<td>60</td>
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<tr>
<td>Palestine</td>
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<tr>
<td>Walking Aids</td>
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</tr>
<tr>
<td>None</td>
<td>139</td>
<td>63</td>
<td></td>
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<tr>
<td>Stick</td>
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<tr>
<td>Crutches</td>
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<td>8</td>
<td></td>
</tr>
<tr>
<td>Walker</td>
<td>33</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Wheelchair</td>
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<tr>
<td>School/University</td>
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<tr>
<td>GMFCS Level II</td>
<td>118</td>
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<td>GMFCS Level III</td>
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<tr>
<td>GMFCS Level II</td>
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<tr>
<td>GMFCS Level III</td>
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<tr>
<td>GMFCS Level IV</td>
<td>13</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

**GMFCS, Gross Motor Function Classification System.**

**Table II: HPA measures of participants’ activity for a mean recording duration of 4 days (SD 5h) according to GMFCS level**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>GMFCS level II ($n=137$)</th>
<th>GMFCS level III ($n=60$)</th>
<th>GMFCS level IV ($n=25$)</th>
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</thead>
<tbody>
<tr>
<td>Sedentary (of 24h)</td>
<td>82.5 (10)</td>
<td>82.1 (7.2)</td>
<td>87.0 (8.4)*</td>
</tr>
<tr>
<td>Standing</td>
<td>11.4 (7.2)</td>
<td>11.9 (5.3)</td>
<td>10.4 (7.0)</td>
</tr>
<tr>
<td>Walking</td>
<td>6.1 (4.8)</td>
<td>6.0 (3.3)</td>
<td>2.6 (2.3)*</td>
</tr>
<tr>
<td>Steps per day</td>
<td>5899 (5804)</td>
<td>6282 (3756)</td>
<td>1956 (2144)*</td>
</tr>
<tr>
<td>Transitions per day</td>
<td>66.2 (35.4)</td>
<td>70.0 (29.0)</td>
<td>50.0 (31.0)*</td>
</tr>
</tbody>
</table>

*Significantly different from GMFCS II ($p<0.001$). **Significantly different from GMFCS level III ($p<0.001$). HPA, habitual physical activity; GMFCS, Gross Motor Function Classification System; IQR, interquartile range.
Those participants spent less time in sedentary behaviour and a larger part of the day in standing and walking activity, with 134 transitions, making them more physically active than participants in GMFCS level II in the present study. Adults in the Netherlands of GMFCS levels III and IV also demonstrated higher levels of physical activity (in terms of walking and transitions) than the participants in the present sample. The Netherlands results conflict with other studies claiming that function and activity reduce with age.6 The differences may be due to the use of different activity monitors, or because participants in the present study experienced restricted access to the appropriate physical environment and structures that would facilitate more activity in their habitual

Figure 1: Median and interquartile range of the duration of events for each activity (sedentary, standing, and walking) and the number of events per day, for Gross Motor Function Classification System (GMFCS) levels II, III, and IV. ***p<0.001.
environment. Another explanation may be that, although adults with CP experience a decrease in fitness and motor function, they often live independently and are, therefore, required to be more active in comparison with participants in this study, who predominantly live with their parents. In the sample from the Netherlands, 60% of participants were living on their own and 70% were working.26

Most previous studies of HPA report levels of activity in terms of step count and duration of each measured posture or activity. However, a new approach has been suggested, based on analysis of events of sedentary behaviour and activity.15 Obeid et al.16 compared sedentary behaviour pattern in 16 children and adolescents with CP (mean age 13 y 1mo, GMFCS levels I, II, and III) and peers with typical development. The two groups showed different patterns, with adolescents with CP showing longer duration of sedentary behaviour and fewer activity breaks. These results agree with those in the present study, in which the median duration of sedentary events was significantly longer in participants of higher GMFCS levels, and the number of separate events (equivalent to the number of breaks) was significantly smaller. Grant et al.27 measured the distribution of sedentary and walking events in older adults, grouped as hospital in-patients, day patients, and a general population. The distribution of activities in those three groups was approximate to that noted in participants of different GMFCS levels in this study; the group with lower mobility function displayed a wider distribution of sedentary events (50% of events were relatively long) and a narrower distribution of walking or upright events (50% of events were relatively short).

The proportion of participants who attended an educational facility and those who stayed at home differed among those of GMFCS levels II, III, and IV (Table I). However, only among participants at GMFCS level III were there significant differences in HPA between student and home-bound participants. We speculate that these differences are due to differences in mobility between these groups. Compared with living at home in the Middle East, the school is a motivating, structured, and physically accessible environment, with flat surfaces and wide pathways that offer improved mobility for those who use walkers and crutches. In our sample, 97% of participants classified as GMFCS level II do not use walking aids, and 84% of participants classified as GMFCS level IV use wheelchairs as their main mobility aid. Therefore, the advantages of supportive facilities are probably most advantageous for participants at GMFCS level III because 78% of these participants use crutches or walkers as their primary mobility aid.

**Clinical implications**

Increasing emphasis is being placed on the definition of sedentary behaviour and the negative influence of its excess on health and wellness.1,2 This study contributes to the body of knowledge of sedentary behaviour of adolescents and young adults with CP by measuring and describing the duration and patterns of HPA in this group. This behaviour event analysis of HPA suggests that consideration be given to interventions that promote physical activity and a healthier lifestyle in this population. In addition to recommendations that encourage a minimal amount of physical activity per day, this study can support recommendations regarding breaks in sedentary behaviour, duration and number of activity bouts, and the importance of accessibility to structured physical facilities, such as those found in schools.

Sedentary behaviour in adolescents with typical development has been measured and guidelines have been issued in Canada that recommend (1) limiting sedentary transport and extended sitting throughout the day and (2) limiting recreational screen time to less than 2 hours per day.28 As this might not be realistic for this population with CP, each bout of daytime sedentary activity should at least be limited to 60 minutes. Moreover, health authorities might
consider adding more specific recommendations for children and adults with CP by incorporating the events concept. Reporting activity data in bouts has the potential to match reported activity against guidelines, e.g. the World Health Organization recommendations that physical activity should be accumulated in at least 10-minute bouts. These might include the number and duration of breaks in sedentary periods and the duration and number of activity bouts. Promoting these goals would be especially beneficial for population with motor disabilities in the Middle East, where such policies do not exist. In addition, this study provides evidence that the physical structure of educational facilities is beneficial for this population.

Limitations
Recording of HPA during four consecutive days, with very limited control over the compliance of the participants during the trial, probably resulted in some faulty records (e.g. misplacing the monitor, prolonged removal after bathing, etc.). Some of these issues were identified as problematic in the early stages of data collection and only a few were encountered during the statistical analysis. In addition, the ActivPAL cannot monitor any physical activity carried out while participants classified as GMFCS level IV were self-propelling a wheelchair or any activities performed in the swimming pool by the whole study population.

CONCLUSION
A novel method for the analysis of HPA, based on the duration and frequency of activity events, was utilized. The results suggest that the event concept within HPA may be considered in updating recommendations for promoting more healthy lifestyles in persons with CP. This study measured the HPA of a large sample of adolescents and young adults with CP in the Middle East, a population that has never been examined with these measurements.

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