Associations Between Meeting the 24-Hour Movement Guidelines and Cardiometabolic Risk in Young Children

Leigh M. Vanderloo
Hospital for Sick Children Research Institute

Jonathan L. Maguire and Charles D.G. Keown-Stoneman
St. Michael’s Hospital and University of Toronto

Patricia C. Parkin and Cornelia M. Borkhoff
Hospital for Sick Children Research Institute and University of Toronto

Mark S. Tremblay
CHEO Research Institute

Laura N. Anderson
McMaster University

Catherine S. Birken
Hospital for Sick Children Research Institute and University of Toronto

on behalf of the TARGet Kids! Collaboration

Introduction: The authors aimed to examine the association between meeting the integrative movement behavior guidelines (physical activity, screen viewing, and sleep) and cardiometabolic risk (CMR) factors in young children. Methods: In this cross-sectional study, physical activity, screen viewing, and sleep were assessed using parent-reported data. The 24-Hour Movement Guidelines for the Early Years (0–4 y) were defined as 180 minutes of physical activity/day (of which ≥60 min should be moderate-to-vigorous intensity), ≤1 hour of screen viewing/day, and 10 to 13 hours of sleep/night. Waist circumference, glucose, high-density lipoprotein cholesterol, triglycerides, and systolic blood pressure were measured in a clinical setting by trained staff. A total CMR score and individual CMR factors served as primary and secondary outcomes, respectively. Results: Of the 767 participants (3–4 y), 26.4% met none of the guideline’s recommendations, whereas 41.3%, 33.1%, and 10.6% of the sample met 1, 2, or all 3 recommendations, respectively. The number of recommendations met was not associated with the total CMR score or individual CMR factors (P ≥ .05), with the exceptions of high-density lipoprotein (odds ratio = 1.61; 95% confidence interval, 1.11 to 2.33; P = .01). Conclusion: Meeting the 24-Hour Movement Guidelines in early childhood was not associated with overall CMR, but was associated with favorable cholesterol outcomes.

Keywords: physical activity, sleep, screen viewing, cardiometabolic health, triglycerides, cholesterol, waist circumference, systolic blood pressure

Understanding the health impact of children’s movement behaviors over a 24-hour period is of importance and interest to parents, healthcare professionals, and researchers. The Canadian 24-Hour Movement Guidelines for Children and Youth were developed to provide public health guidelines that integrated recommendations for physical activity, sedentary behaviors, and sleep for children aged 5–17 years (52). Children and youth who adhere to these new guidelines have healthier body composition, cardiorespiratory and musculoskeletal fitness, academic achievement and cognition, emotional regulation, prosocial behaviors, cardiovascular and metabolic health, and overall quality of life (11,13,16,41,46).

Extending to the early years, integrative movement behavior guidelines were developed for children aged 0–4 years to provide guidance regarding healthy physical activity, sedentary behaviors, and sleep hygiene (53). National surveillance data suggest only 13% of 3- to 4-year-olds in Canada meet all 3 recommendations within the Canadian 24-Hour Movement Guidelines for the Early Years (18). A high proportion of 3- to 4-year-olds in Canada are meeting the physical activity (62%) and sleep (84%) recommendations, but only 24% are meeting the screen time recommendation (18). Various studies have been conducted to explore the relationship between movement behaviors and various health outcomes in the early years, including motor development, psychosocial health, cognitive development, and fitness (12,17,34,42). Missing from our understanding is the association among young children’s ability to meet various components of the newly integrated 24-
Hour Movement Guidelines for the Early Years and their cardiometabolic health.

Cardiometabolic risk (CMR) factors are commonly referred to as characteristics or markers that contribute to cardiovascular disease and the development of type 2 diabetes (8). CMR in childhood may be an important intermediate outcome that can be measured before adolescent and adult disease onset and provide opportunities for prevention (21,47). Among school-aged children, Katzmarzyk and Staiano (32) reported that meeting an increased number of recommendations from the 24-Hour Movement Guidelines for Children and Youth (52) was associated with lower levels of CMR factors (namely, glucose and triglycerides) and obesity among children aged 5–17 years (32). Measures of cardiovascular and metabolic risk, including obesity, dyslipidemia, and elevated glucose and blood pressure, cluster together in young children (3,6,36,39,42). Emerging evidence suggests that CMR is initiated in early life, tracks from childhood into adulthood, and may predict future diabetes and cardiovascular disease (4,31,33,37), but very little is known about movement behaviors and CMR in children under 5 years. Given the above evidence that only a small proportion of young children are meeting the newly adopted 24-Hour Movement Guidelines, it is important to determine the effects of this integration of movement behaviors as it relates to CMR. To date, and in part attributed to the challenges and costs of collecting the associated laboratory measures, no investigations have examined the association between integrative movement guidelines and CMR in a population-based sample of children under 5 years.

Movement behaviors that are established early in life may persist across the lifespan (5,29,35,44,54) and affect cardiometabolic health. Building on the previously published work by Katzmarzyk and Staiano (32) with school-aged children, and coupled with the fact that no standardized definition for CMR in young children currently exists, the overarching purpose of this study was to examine the relationship between adherence to Canada’s 24-Hour Movement Guidelines for the Early Years (53) and CMR in young children. The primary objective was to examine the association between meeting each individual guideline and a continuous CMR cluster score and individual risk factors. The secondary objective was to examine the association between the number of guideline components met and the odds of improved CMR outcomes.

Methods

Participants

As part of a larger study, children <6 years of age were recruited to participate in a primary care, practice-based research network in a large city and were followed during scheduled health supervision visits. Of these participants and for the purposes of this study, a cross-sectional subset of children aged 3–4 years were examined. Parents provided written consent for their child’s participation in the study, and all materials and protocols received institutional approval from the Hospital for Sick Children and St. Michael’s Hospital (REB #1000012436).

Inclusion and Exclusion Criteria

Children were eligible to participate in the present study if they were between the ages of 3 and 4 years, and had concurrent measures of physical activity, screen use and sleep (exposures), and CMR measures (outcome) available on one or more visits. Children were not included at enrollment if they had any chronic health condition (except for asthma) or severe developmental delay, or if their parents/guardians were unable to complete the consent and questionnaires in English. Children <3 years of age were excluded from this study since blood pressure was not collected in this age group.

Movement Behaviors—Exposure Variable

Data on the participants’ physical activity, screen viewing, and sleep were obtained from a standardized parent-reported questionnaire. The questionnaire was supplied to parents at the start of their child’s routine health supervision visit, and they were asked to return the completed questionnaire prior to leaving. The parents were instructed to provide open-ended responses reporting how many minutes or hours per weekday and weekend day their child participated in physical activity (any intensity activity and high-intensity energetic play), screen use activities, and sleep (on average). From here, total daily averages for each of the individual behaviors were derived by summing the total number of minutes or hours of physical activity/screen use/sleep during the week and over the weekend, for example, (average daily screen use on weekday ×5 + average daily screen use on weekend day × 2)/7. Meeting the 24-Hour Movement Guidelines (yes/no), inclusive of the individual behavior recommendations (yes/no), was defined as accumulating a minimum of 180 minutes of physical activity per day (of which at least 60 min is high-intensity energetic play), engaging in a maximum of 1 hour of screen use per day, and getting 10 to 13 hours of sleep per night (53). See Supplementary Table S1 (available online) for specific questions asked to collect information on each of the 3 movement behaviors.

Cardiometabolic Risk Factors—Outcome Variables

Trained research staff measured waist circumference and systolic blood pressure and collected nonfasting blood samples at each scheduled health supervision visit, using standard clinical procedures (9). Waist circumference was assessed using an anthropometric measuring tape above the child’s iliac crest. Mercury sphygmomanometers or automated oscillatory devices were used to measure systolic blood pressure, and appropriate child blood pressure cuff sizes were used. For research purposes, obtaining fasted blood samples from young children in a clinical setting can be challenging; however, previous studies (48), including our team’s (2), have shown that the duration of fasting has minimal impact on lipids and glucose in children. Nonfasting blood samples to assess the concentrations of triglycerides, glucose, and high-density lipoproteins were performed at Mount Sinai Laboratory (Toronto, Canada) and analyzed using standard procedures. The time of last drink (except for water) and last snack were recorded by the research staff during the collection of blood to adjust for fasting hours.

Using the Eisenmann protocol (21,22), a continuous total CMR score was derived for each participant. This was achieved by taking the sum of the individual CMR factor z scores from the waist circumference, glucose, (additive inverse) high-density lipoprotein cholesterol (HDL-c), triglycerides, and systolic blood pressure, and then dividing by the square root of 5. The z scores were calculated using the mean and SD within our population, as has been done in other cohorts (21,40). The inverse of HDL-c was used in the score since higher HDL-c is indicative of a better metabolic profile. A lower total CMR score indicates lower CMR. Similar CMR scores have been used in the literature to assess CMR in children and adolescents (15,19,20,30,38). For the
individual components, elevated CMR factors were defined as follows, based on age and sex: HDL-c < 1.17 mmol/L (25), triglycerides ≥ 0.84 mmol/L (25), systolic blood pressure ≥ 90th percentile (stratified by age, sex, and height [26]), or ≥ 90th percentile in instances where defined cut-off criteria were absent (glucose and waist circumference). The cut-off for the total CMR dichotomous outcome score was ≥ 90th percentile of the total CMR score.

Other Variables—Covariates

Potential confounding variables were identified a priori based on previous literature and were collected via the aforementioned parent-reported child health questionnaire. These variables included the child’s age and sex, maternal education, maternal ethnicity, family history of cardiovascular disease, fasting hours, and annual household income (14,42,49).

Statistical Analyses

Descriptive characteristics were computed for the exposures, outcome, and covariates. Multiple imputation analysis using 10 imputed datasets was performed to allow the inclusion of subjects with missing covariate data (up to 10% missing) using the “mice” package in R (7). The results of the imputed datasets were combined, and the parameter estimates (95% CIs) for the adjusted pooled models were reported. All variables had levels of missing data under 15% (24).

For the primary objective, separate general linear models were used to examine the association between meeting each individual component of the guidelines and the continuous outcomes of the total CMR score and individual factors. For the secondary objective, we used multivariable logistic regression to examine the association between each guideline component and elevated CMR, wherein “meeting none of the guidelines” served as the reference group. Age and sex (waist circumference, glucose, HDL-c, triglycerides, and systolic blood pressure), fasting time (glucose, HDL-c, and triglycerides), and height (systolic blood pressure) were included as covariates in all models. All analyses were carried out using R (version 3.4.0; https://www.R-project.org).

Results

The data from a total of 767 children were eligible for analysis (see Figure 1 for flow chart). The descriptive statistics of the sample are presented in Table 1, and all questionnaires were completed by mothers. The average age of the participants was 3.58 years (SD = 0.81 y), and 49.3% were females. The proportion of participants meeting the recommendations of the 24-Hour Movement Guidelines for the Early Years (53) is presented in Table 2. Here, 25.4% of children met none of the guidelines, whereas 41.3%, 23.1%, and 10.2% of the children met 1, 2, or all 3 guidelines, respectively. Proportions of the guidelines met did not significantly differ based on sex.

The mean CMR cluster score was −0.25 (2.19), ranging from −7.11 to 9.26. The results of the general linear models are presented in Table 3. No significant associations were identified between meeting 1, 2, or 3 of the guidelines and a continuous CMR score or individual CMR factors, except for HDL-c (P < .01). The associations between meeting guideline recommendations and the odds of elevated CMR are presented in Table 4. The results indicate no evidence of an association between meeting the guidelines and dichotomous CMR score or individual CMR factor cutoffs, except for HDL-c. Meeting all 24-hour movement guidelines was associated with reduced odds of unfavorable HDL-c (odds ratio = 1.61; 95% confidence interval, 1.11 to 2.33; P = .01).

Figure 1 — Participant eligibility flow chart. CMR indicates cardiometabolic risk.
In this study, we examined the association between meeting the 24-Hour Movement Guidelines for the Early Years (53) and CMR in children 3–4 years of age, wherein only 10% of the children in the sample met all 3 recommendations outlined in the integrated movement behavior guidelines. These findings are corroborated by Chaput et al (18), who found that 13% of preschoolers in Canada met all 3 recommendations. Similar trends continue to persist in older children (10,32,19). Roman-Vinas et al (19) found that 14% of 10-year-olds in Canada, 2.1% in the United States, and 7.2% of 10-year-old children worldwide from 12 different countries met these guidelines. Furthermore, our results are consistent with published work with older children, whereby similar proportions of children meeting the various components of the integrated movement behaviors were reported (32). Katzmarzyk and Staiano (32) reported that a total of 26.9% of the sample of children (mean age = 12 y) met none of the 3 guidelines, whereas 36.4%, 28.3%, and 8.4% of the sample met 1, 2, or all 3 of the guidelines, respectively. Given the published work to date, the prevalence of children meeting the 24-hour integrated behavior guidelines is low (45). To ensure that adequate levels of healthy movement behaviors track throughout the lifespan, efforts to support children

### Table 1 Descriptive Characteristics of Sample (n = 767)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>3.58 (0.81)</td>
<td></td>
</tr>
<tr>
<td>Maternal ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Asian</td>
<td>68 (8.8)</td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>494 (64.4)</td>
<td></td>
</tr>
<tr>
<td>South/Southeast Asian</td>
<td>59 (7.7)</td>
<td></td>
</tr>
<tr>
<td>African and Latin American</td>
<td>103 (13.4)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>43 (5.6)</td>
<td></td>
</tr>
<tr>
<td>Cardiometabolic risk factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>57.4 (11.2)</td>
<td></td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>4.1 (1.4)</td>
<td></td>
</tr>
<tr>
<td>High-density lipoprotein cholesterol, mmol/L</td>
<td>1.5 (0.76)</td>
<td></td>
</tr>
<tr>
<td>Triglycerides, mmol/L</td>
<td>3.4 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>91 (24.0)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 Proportion (in Percentages) of Participants Meeting the Individual Recommendations of the 24-Hour Movement Guidelines for the Early Years (0–4 y)

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Total</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>25.4</td>
<td>26.0</td>
<td>24.8</td>
</tr>
<tr>
<td>Physical activity (180 min, including 60 min high-intensity energetic play)</td>
<td>45.4</td>
<td>48.6</td>
<td>42.2</td>
</tr>
<tr>
<td>Screen viewing</td>
<td>39.8</td>
<td>41.3</td>
<td>38.3</td>
</tr>
<tr>
<td>Sleep</td>
<td>51.7</td>
<td>49.8</td>
<td>53.6</td>
</tr>
<tr>
<td>Physical activity + screen viewing</td>
<td>15.6</td>
<td>18.9</td>
<td>12.3</td>
</tr>
<tr>
<td>Physical activity + sleep</td>
<td>19.2</td>
<td>16.6</td>
<td>21.8</td>
</tr>
<tr>
<td>Screen viewing + sleep</td>
<td>22.8</td>
<td>21.2</td>
<td>24.3</td>
</tr>
<tr>
<td>All 3 recommendations</td>
<td>10.2</td>
<td>11.7</td>
<td>8.7</td>
</tr>
</tbody>
</table>

### Table 3 Adjusted Means (SEs) and CIs for CMR and Meeting Components of the 24-Hour Movement Guidelines per the General Linear

<table>
<thead>
<tr>
<th>Variable</th>
<th>None (n = 102)</th>
<th>1 (n = 330)</th>
<th>2 (n = 254)</th>
<th>3 (n = 81)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SE); 95% CI</td>
<td>Mean (SE); 95% CI</td>
<td>Mean (SE); 95% CI</td>
<td>Mean (SE); 95% CI</td>
<td></td>
</tr>
<tr>
<td>Total CMR score</td>
<td>0.8 (3.8); [−6.65 to 8.25]</td>
<td>−2.4 (3.0); [−8.28 to 3.48]</td>
<td>−1.8 (4.6); [−10.82 to 7.22]</td>
<td>−6.6 (2.1); [−10.72 to −2.48]</td>
<td>.82</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>41.3 (0.3); [40.71 to 41.89]</td>
<td>40.0 (0.9); [38.24 to 41.76]</td>
<td>38.7 (0.2); [38.31 to 39.09]</td>
<td>36.2 (1.4); [33.61 to 36.79]</td>
<td>.88</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>4.0 (0.2); [3.61 to 4.49]</td>
<td>3.9 (0.9); [2.13 to 5.66]</td>
<td>3.8 (0.3); [3.21 to 4.39]</td>
<td>3.6 (0.3); [4.01 to 4.19]</td>
<td>.12</td>
</tr>
<tr>
<td>High-density lipoprotein, mmol/L</td>
<td>46.8 (13.7); [19.95 to 73.65]</td>
<td>46.0 (10.4); [25.62 to 66.38]</td>
<td>48.7 (12.5); [24.30 to 73.20]</td>
<td>52.8 (11.6); [30.06 to 75.54]</td>
<td>.01</td>
</tr>
<tr>
<td>Triglycerides, mmol/L</td>
<td>70.8 (10.1); [51.00 to 90.60]</td>
<td>72.4 (9.8); [53.19 to 91.61]</td>
<td>64.0 (12.8); [38.91 to 89.09]</td>
<td>60.1 (10.6); [39.32 to 80.88]</td>
<td>.20</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>101.8 (3.8); [109.25 to 94.35]</td>
<td>101.3 (2.3); [96.79 to 105.81]</td>
<td>100.9 (1.3); [98.35 to 103.45]</td>
<td>101.5 (0.6); [100.32 to 102.68]</td>
<td>.07</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; CMR, cardiometabolic score; HDL-c, high-density lipoprotein cholesterol. Note: Models were adjusted for age, sex, fasting time (for waist circumference, glucose, HDL-c, and triglycerides), height (systolic blood pressure), maternal education, maternal ethnicity, family history of cardiovascular disease, and annual household income. Bold indicates alpha was set at 0.05.
in developing strong habits at a very young age should remain a priority, particularly when such lifestyle behaviors are more malleable (28).

We identified a significant association between meeting all guidelines and favorable HDL-c outcomes. Similarly, Ekelund et al. (23) examined the association between moderate to vigorous physical activity, sedentary time, and CMR in a total of 2781 (4- to 8-year-old) children and found that MVPA was associated with significantly higher values of HDL-c across tertiles for sedentary time. Likewise, Carson et al. (n = 4157; 6–17 y [10]) found that meeting more components of the guidelines was associated with higher levels of HDL-c and more favorable blood pressure. It is relatively known that, among children, levels of HDL-c tend to be elevated at this young age. Conversely, triglycerides and low-density lipoprotein cholesterol are less responsive and may require a longer exposure load before variability can be detected (50), thus partially explaining the lack of findings in this young age group. As HDL-c has been shown to track from late childhood into adulthood (1,27), it remains an important marker of cardiometabolic health, which warrants additional focus.

Unlike the work conducted by Katzmarzyk and Staiano (32), which reported significant associations between the number of guidelines met and triglycerides and glucose among a school-age sample, we did not recount any additional significant associations with the remaining individual CMR markers. The absence of an association between meeting the 24-Hour Movement Guidelines and the remaining individual CMR factors among young children could be attributed to the small number of children in this age group being at high CMR or, perhaps in this context, it is too early to detect a true association between the variables being explored. The later notion may be further supported by findings from the nationally representative Canadian Health Measures Survey (cycle 2: 2009–2011 and cycle 3: 2012–2013), which demonstrated time spent in each movement behavior was not associated with waist circumference or BMI z scores in predominantly term-born preschool-aged children (11). Nonetheless, given the mixed or null findings regarding children’s CMR and integrative movement behaviors, additional confirmatory studies are required, and young children should still be encouraged to engage in healthy levels of daily physical activity, screen use, and sleep for overall health and development.

### Strengths and Limitations

The large sample size of young children and the clinical and laboratory measurements are noteworthy strengths of this study. The main limitation of this study was the use of self-reported data to assess the integrated movement behaviors, which can be limited by recall and bias. However, the exposure variables examined in this study were taken from a validated national survey (51). The cross-sectional design of this study is also a limitation, as it precludes the possibility of making inferences regarding cause and effect, and there may be unmeasured confounding. Because only mothers completed the study questionnaires, we were only able to include information on maternal education and ethnicity. There is currently no standardized definition for defining CMR in young children, and multiple approaches exist to calculate related scores (21,47). However, this paper utilized the Eisenmann scoring approach (21), which has demonstrated strong agreement and construct validity in slightly older children (7–9 y [22]).

### Conclusion

Only a small percentage of young children in this sample met all 3 recommendations of the 24-Hour Movement Guidelines for the Early Years. Apart from HDL-c, evidence of an association between meeting components of the 24-Hour Movement Guidelines (53) and overall CMR score or other individual CMR factors was not identified. It is possible that the exposure—meeting the guidelines—may be too crude of a measure, and the next steps may include exploring each of the movement behaviors continuously and examining the outcomes individually. To promote healthy development and prevent early disease onset, future interventions should consider strategies that simultaneously improve physical activity, screen use, and sleep while examining their association with CMR outcomes throughout childhood to observe whether the findings from this paper persist.

### Acknowledgments

The funding agencies had no role in the design and conduct of the study, the collection/analysis, interpretation of the data, or the preparation and approval of the manuscript. The authors have no conflict of interest to declare. The PCP reports receiving the following grants unrelated to this

### Table 4  Logistic Regression Models for Meeting Specific Movement Guideline Recommendations and the Odds of Elevated CMR

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 Recommendation (n = 330)</th>
<th>2 Recommendations (n = 254)</th>
<th>3 Recommendations (n = 81)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>P</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>Total CMR score</td>
<td>1.48 (0.88 to 3.94)</td>
<td>.08</td>
<td>1.94 (0.94 to 3.98)</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>1.03 (0.52 to 2.03)</td>
<td>.94</td>
<td>1.04 (0.63 to 1.69)</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>0.92 (0.68 to 1.24)</td>
<td>.58</td>
<td>0.94 (0.37 to 2.37)</td>
</tr>
<tr>
<td>High-density lipoprotein cholesterol, mmol/L</td>
<td>0.7 (0.40 to 1.27)</td>
<td>.25</td>
<td>0.77 (0.34 to 1.77)</td>
</tr>
<tr>
<td>Triglycerides, mmol/L</td>
<td>1.12 (0.92 to 1.36)</td>
<td>.27</td>
<td>1.03 (0.68 to 1.56)</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>4.19 (0.97 to 18.11)</td>
<td>.06</td>
<td>1.96 (0.75 to 5.09)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; CMR, cardiometabolic risk; HDL-c, high-density lipoprotein cholesterol; OR, odds ratio. Note: Models were adjusted for age, sex, fasting time (for waist circumference, glucose, HDL-c, and triglycerides), height (systolic blood pressure), maternal education, maternal ethnicity, family history of cardiovascular disease, and annual household income. High risk cutoffs: HDL-c < 1.17 mmol/L (25), triglycerides ≥ 0.84 mmol/L (25), systolic blood pressure ≥ 90th percentile (on the basis of age, sex, and height tables [26]), or ≥ 90th percentile in instances where defined cut-point criteria were absent (glucose and waist circumference). Bold indicates alpha was set at 0.05.
study: a grant from the Canadian Institutes of Health Research (FRN #115059) for an ongoing investigator-initiated trial of iron deficiency in young children, for which Mead Johnson Nutrition provides nonfinancial support (Fer-In-Sol® liquid iron supplement; 2011–2017); and peer-reviewed grants for completed investigator-initiated studies from Danone Institute of Canada (2002–2004 and 2006–2009), Dairy Farmers of Ontario (2008–2010). L.M.V. received an unrestricted research grant for a completed investigator-initiated study from the Dairy Farmers of Canada (2011–2012), and Ddrops provided nonfinancial support (vitamin D supplements) for an investigator-initiated study on vitamin D and respiratory tract infections (2011–2015). C.M.B. reports previously receiving a grant for a completed investigator-initiated study from the SickKids Center for Health Active Kids (CHAK; 2015–2016), involving the development and validation of a risk stratification tool to identify young asymptomatic children at risk for iron deficiency. These agencies had no role in the design, collection, analyses, or interpretation of the results of this study or in the preparation, review, or approval of the manuscript. L.M.V. and C.S.B. conceptualized the study. L.M.V. and C.D.G.K. were responsible for the data cleaning/data analysis. L.M.V. wrote the initial draft of the manuscript. All authors provided feedback on the drafts and approved the final manuscript. This study was supported by the Canadian Institutes of Health Research (CIHR), The Hospital for Sick Children Foundation (with a grant to the Paediatric Outcomes Research Team), and St. Michael’s Hospital Foundation. L.M.V. was supported by a CIHR Fellowship Award. The authors would like to thank the child participants and their families for their participation in this study, as well as to all clinicians who are currently involved in the TARGet Kids! practice-based research network.


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