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Reduction in ambulatory distance from childhood through adolescence: The impact of the number and length of steps



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ABSTRACT

Background: The aim of this study was to explore the relationship between ambulatory distance with steps/day and increased step length as children age.

Methods: This is a prospective cohort study. Forty-five children from the QUALITY cohort were assessed at childhood (baseline) and seven years later during adolescence (follow-up). Daily step count was evaluated by accelerometry, step length by a standardized test, and daily ambulatory distance was calculated based on step count and length.

Results: Children grew by an average of 0.33 m from childhood to adolescence ($p < 0.001$). The daily ambulatory distance decreased by an average 3008 m from childhood to adolescence ($p < 0.001$). Step length increased an average of 0.10 m ($p < 0.001$) from childhood to adolescence, while the number of steps taken decreased by an average of 5549 steps (childhood to adolescence) ($p < 0.001$). The change in the number of steps between childhood and adolescence represents 84.6% of the change in the ambulatory distance while the change in step length explained an additional 13.0%

Conclusions: The decrease in the ambulatory distance from childhood to adolescence was strongly explained by the decrease in step count; however the increase in step length should not to be neglected.

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1. Introduction

Physical activity (PA) levels have been shown to decrease as children age.¹ Colley et al. have shown that Canadian children (ages 6–10 years old) take on average 12,530 steps per day, amounting to 64 min of moderate-to-vigorous PA (MVPA) per day.² During adolescence (ages 15–19 years old), this amount is reduced to

10,098 steps and 45 min of MVPA per day.² Physical activity can be assessed using objective measures, such as wearable accelerometers, which provide information concerning the amount of steps taken and the duration spent in different intensities of PA. This type of information is essential for the identification of children and adolescents who may be engaging in low levels of PA and living at an elevated risk of acquiring health problems such as overweight/obesity, cardiovascular disease and diabetes.^{3,4}

Although steps/day is a widely used criterion to estimate the total volume of ambulatory activity; unlike MVPA, which has focused guidelines of at least 60 min of MVPA per day, there is great variability in the recommendations concerning steps/day for reducing cardiovascular disease risk.^{4,5} In a recent review, Silva et al. concluded that recommendations should range from 10,000 to 16,000 steps/day for body mass index (BMI) and body fat

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outcomes (5–16 years old), and from 9000 to 14,000 steps/day for PA outcomes (6–19 years old).⁴ More specifically, Tudor-Locke et al.⁵ reported that the minimal recommendation of 60 min of MVPA for youth is represented by 13,000 to 15,000 steps/day in boys aged 5–13 years old, 11,000 to 12,000 steps/day in girls aged 5–13 years old, and 10,000–11,700 steps/day for adolescents of both sexes in a free-living environment.

As children grow, their limbs become longer, which has an impact on their step length.⁶ For example, an average 8-year-old girl whose legs measure 0.60 m will have an average step length of 0.54 m,⁷ yielding 5.9 km per day for 11,000 steps. In comparison, an 13-year-old girl after maturity with a leg length of 0.78 m would have a mean step length of 0.83 m, resulting in 9.1 km for the same 11,000 steps/day.⁸ An ambulatory activity can be defined by step count, walking distance, total time in movement, or energy expenditure; each of which require a different interpretation.⁹ For example, adolescents of different heights may walk the same distance in the same amount of time, but taller individuals will have taken fewer steps due to their greater leg and step length, expending less overall energy. Energy expenditure is determined by body size and body composition, as well as environmental and behavioral determinants.¹⁰ Physical activity is an important behavioral determinant of energy expenditure, and changes in walking activity may affect energy balance, leading to the development of health problems, such as obesity.¹⁰ Therefore, understanding how ambulatory activity metrics functions together is fundamental to understanding how walking activity evolves with age.⁹ The aim of this study was to explore the relationship between ambulatory distance with step count and step length as children grow into adolescence. The hypotheses are that step length increases with age and this increase is related to the number of steps and the ambulatory distance in adolescence.

2. Methods

Data from the Quebec Adiposity and Lifestyle Investigation in Youth (QUALITY) cohort¹¹ were used for the current study. Participants were Caucasian and aged 8–10 years at study entry, and all participants had at least one biological parent with overall or abdominal obesity. Participants attended a baseline visit (childhood: 8–10 years old, n = 630) and a follow-up visit seven years later (adolescence: 15–18 years old, n = 359). Data for the present analyses were retrieved from a subsample that completed the step length test and had valid accelerometry data at baseline and follow-up (n = 45) (dropouts' information is presented in supplementary material 1).

Body weight was measured using an electronic scale.¹² Height was measured using a stadiometer.¹² Age- and sex-specific BMI z-score was calculated according to the World Health Organization guidelines.¹³

Free-living PA was assessed using a uniaxial activity monitor (7164, Actigraph LLC, Pensacola, FL, USA) at baseline and a newer generation of the activity monitor (Triaxial; GT3X, Actigraph LLC, Pensacola, FL, USA) at follow-up due to device failure over 7 year period. Activity monitors were worn for a 7-day period positioned on the right hip, held in place with an elastic waistband during the daytime, and removed for sleep as well as bathing and aquatic activities. Accelerometry data were downloaded as 1-min epochs and underwent standardized quality control and data reduction procedures.¹⁴ Although activity monitors used during adolescence were initialized in a triaxial mode, only data from the y-axis were analysed to increase similarity in physical activity measurements to those from earlier visits with the GT3X monitor. Daily step count was computed using ActiLife v6.13.3 (Actigraph LLC, Pensacola, FL, USA). Accelerometry data were valid if wear-time was ≥10 h daily

for ≥3 weekdays and 1 weekend day.¹⁵ Non-wear time was defined as at least 60 consecutive minutes of zero counts, with allowance for 1–2 min of counts between 0 and 100.¹⁶ The variable of interest was number of steps averaged per day.

A standardized test, similar to that used in previous studies,¹⁷ was administered to measure the average step length of this sample (see supplementary material 2). On a level floor, a first line was placed at 0 m, a second at 10.25 m, and a third at 13 m. The distance between the first and second lines represented 10 m plus half the distance of a regular step for the age group at first visit (i.e., 0.25 m).⁷ The third line corresponded to the finish line, a target used to ensure the child kept a constant pace from the first to the second line. All steps taken between the first and second lines were monitored. In order to remove the initiation steps, a marker was placed during each trial to identify the heel of the fourth step. The test was administered four times. The ambulatory distance (10.25 m - the heel on the fourth step) and the actual number of steps taken were used to calculate the mean step length of each trial. The daily ambulatory distance was calculated by multiplying the average number of steps/day by the average length of steps.

Descriptive statistics were calculated to characterize the sample. Repeated measures ANOVA was used to compare average step length, step count, and ambulatory distance between baseline and follow-up. Pearson correlations were used to examine the association between the change in number of steps and step length with change in ambulatory distance from childhood to adolescence. Multiple linear regression was performed to evaluate the association between the changes in ambulatory distance from childhood to adolescence with the changes in step length and step count between childhood and adolescence. The power for the analyses was set to be 0.08 and the α was 0.05. All analyses were performed using IBM SPSS Statistics, version 25 (IBM SPSS Statistics, Version 25.0. Armonk, NY, USA).

This study was approved by the institutional ethics review boards of the Sainte-Justine University Hospital Centre and the Quebec Heart and Lung Institute. Written informed parental consent and child assent were obtained.

3. Results

Mean age was 9.6 ± 1.1 years at baseline and 16.9 ± 1.1 years at follow-up. Children grew by an average of 33 cm from childhood to adolescence (p < 0.001) (Table 1). Daily ambulatory distance decreased significantly over the 7-year follow-up period, (childhood to adolescence: 3008 m) [interquartile range (IQR) = 3945 m, p < 0.0001] (Table 1). From childhood to adolescence, step length increased (Mean Δ = 0.10 m, IQR = 0.14 m), while the step count decreased (Mean Δ = -5718 steps, IQR = 4943 steps).

Fig. 1 shows the Pearson correlation for the change in ambulatory distance from childhood to adolescence with the change in the

Table 1
Participant characteristics.

n = 45	Childhood (Baseline)	Adolescence (Follow-up)
Male (%)	57.8	57.8
Age (years)	9.6 ± 1.1	16.9 ± 1.1*
Body weight (kg)	35.9 ± 8.0	70.1 ± 12.5*
Height (cm)	139.5 ± 7.4	172.1 ± 7.3*
BMI (z-score)	0.82 ± 0.84	0.52 ± 0.90
Ambulatory distance (m)	8601 ± 2166	5593 ± 1850*
Step count	12,842 ± 2775	7293 ± 2311*
Step length (m)	0.67 ± 0.08	0.77 ± 0.08*

Values are mean ± standard deviation, unless otherwise specified; BMI: Body mass index.

*Significant difference between baseline and follow-up (p < 0.05).

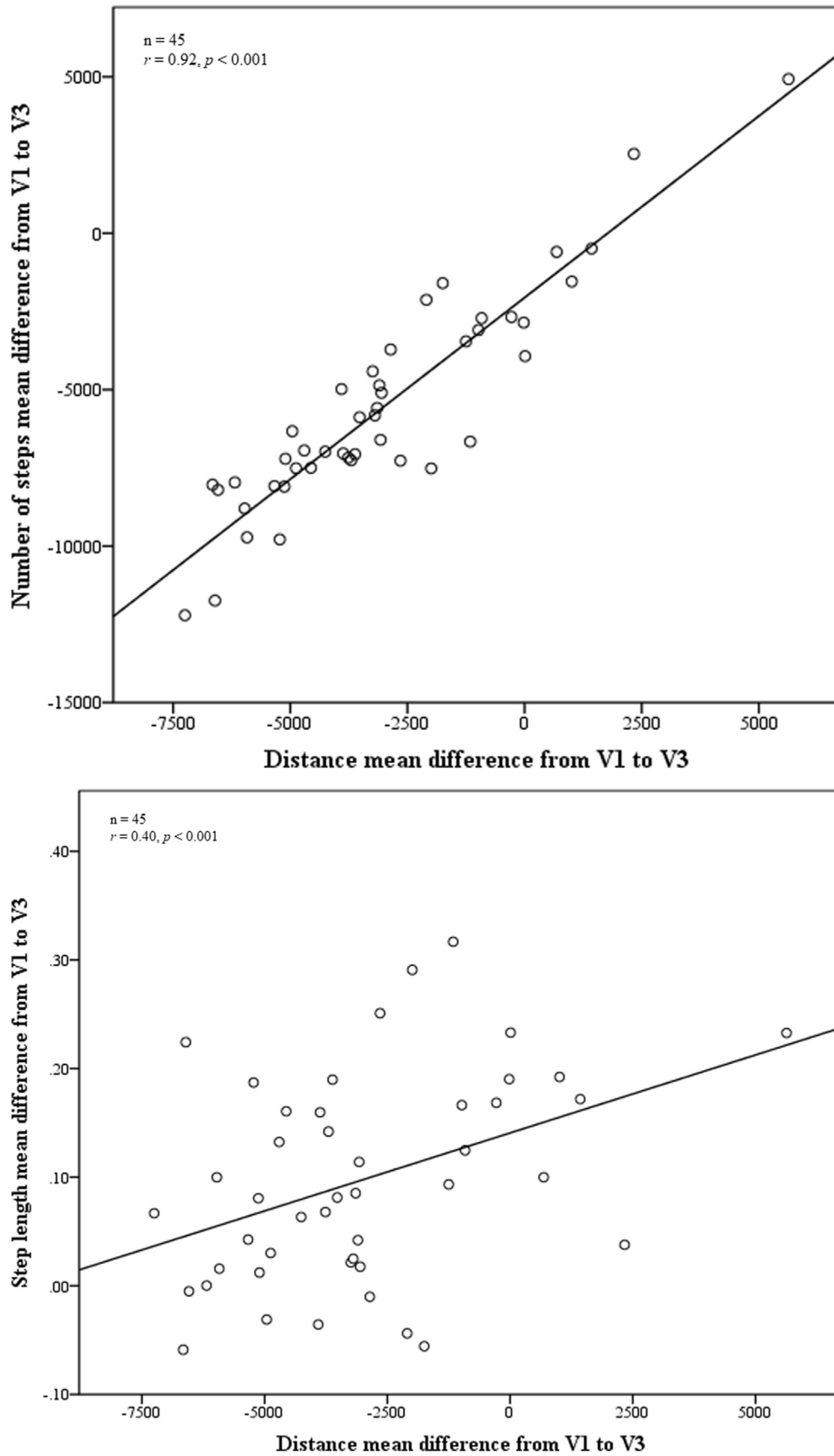


Fig. 1. Correlation of the change in ambulatory distance with the change in the number of steps (a) and the step length from baseline (childhood) to follow-up (adolescence) (b), respectively.

number of steps (Fig. 1a.) and the step length during the same period (childhood to adolescence) (Fig. 1b.). There was a stronger correlation between the reduction in ambulatory distance and the decrease in number of steps from childhood to adolescence ($r = 0.92$, $p < 0.001$) when compared to the increased step length during this period ($r = 0.40$, $p < 0.001$). There was no correlation between the decreased step length and in number of steps ($r = 0.08$, $p = 0.53$) from childhood to adolescence.

Table 2 shows associations between the change in ambulatory distance from childhood to adolescence, with the change in step count and step length during this time frame. The decrease in step count had a greater influence on the decrease in ambulatory distance ($\beta = 0.90$, $p < 0.001$) when compared to the increase in step length ($\beta = 0.36$, $p < 0.001$) (Table 2). The decrease in step count between childhood and adolescence represents 84.6% of the decrease in ambulatory distance, while the increase in step length explained an additional 13.0% of the decrease in ambulatory distance from childhood to adolescence (Table 2).

4. Discussion

The aim of this study was to explore the relationship between ambulatory distance with step count and step length as children grow into adolescence. Results showed that participants' ambulatory profile changed over the 7-year follow-up period. The daily ambulatory distance decreased substantially from 10 to 18 years of age. From childhood to adolescence, step length increased, while step count decreased. The present study revealed that the decrease in step count between childhood and adolescence represented 84.6% of the change in ambulatory distance and that the increase in step length explained an additional 13.0%.

The decrease in ambulatory distance was associated with a decrease in step counts,⁹ but also highlighted the effect of an increased step length.¹⁸ These findings agree with Beets et al.,¹⁹ which demonstrated that leg length has a substantial impact on the estimated step counts in a controlled laboratory environment. The results of the present study add new information to this relationship, since step count was measured in a free-living environment and included a longitudinal design. This inverse relationship between longer step length and step count is typically observed during childhood.²⁰ Throughout childhood and adolescence, these changes in ambulatory profiles may increase the risk of weight gain and cardiovascular disease as a result of affected total energy expenditure.^{10,21}

Eisenmann et al.⁹ showed that step count taken and the energy expended for a particular task is greater in smaller children. The increased step length among growing children results in older children achieving a greater distance with the same number of steps than their smaller peers.⁹ Our study showed that the increased step length significantly explained the decrease in ambulatory distance noted. Participants walked shorter distances, despite having longer step length, because they took fewer steps. Therefore, if a child of 8–10 years of age is respecting the guidelines achieving 12,000 steps/day, by the time they reach 13 years of age and maintain the same ambulatory distance, they will be stepping 1560 steps less per day, representing 569,400 less steps annually.

This decrease tends to get worse with age.

The increase in average step length from childhood to adolescence is principally determined by growth and maturation processes.⁶ Moreover, the decrease in the ambulatory distance and consequently in the PA volume during adolescence can be explained by the decrease in the number of steps taken,^{18,20,22,23} which is a substantial reason for this significant reduction. Additionally, this estimated decrease in total ambulatory activity is more precise after considering the step length measurement,¹⁸ as shown in our results. In fact, the ambulatory distance would be further decreased if the step length would not have increased with age. The changes in step length limit further decrease in ambulatory distance from childhood to adolescence. Ambulatory distance and step length are related to each other, and leg length largely determines the step frequency and the metabolic cost during movement.¹⁹

Replication of our outcomes in a larger and more diverse sample is warranted including additional variables such as walking speed and mechanical efficiency, which appear to be contributing factors to total energy expenditure. It is known that the energy expended to walk a fixed distance can be greater for smaller versus larger individuals.²⁴ Also, energy expenditure is linearly associated with walking speed, which means that as speed increases, the associated energy expenditure similarly increases.²⁵ Future such studies would make relevant contributions and have implications for improving the accuracy of PA and energy expenditure assessment.

As a convenience sample was used, generalizability to other populations is unknown. The main strengths of the present study were the longitudinal design and the high-quality objective measures of PA. This study provides foundational evidence supporting the importance of step count and the step length to more accurately predict the ambulatory distance in children and adolescents. The model of the ActiGraph activity monitor that was used at baseline (7164) was an older generation than the monitor used at follow-up (GT3X). This change in device was done because the 7164 monitor was discontinued by the company at the time of the QUALITY Visit 3 assessment. Reports comparing these different generations of ActiGraph in a free-living environment with a youth population indicate that the 7164 demonstrates a 9.4% mean difference compared to the GT3X.²⁶ This mean difference would have negligible effects on our findings and would only account for 477 steps of the total 5549 step difference between childhood and adolescence. Although measurements acquired using these two monitors may differ, in both cases we relied on data from a single axis, on the same monitor placement and on the same cut-points for moderate and vigorous physical activity. However, our results should be interpreted considering the ActiGraph limitation of measuring steps,²⁷ especially at lower speeds. At slower walking speeds, smaller accelerations are detected during the contralateral step, which may not satisfy the step-count criteria, yielding fewer steps than it should be identified.²⁷

5. Conclusion

We observed that ambulatory profiles change substantially from childhood to adolescence; while the decrease in ambulatory distance was strongly explained by the decreased number of steps,

Table 2

Associations between the change in ambulatory distance with the changes in number of steps and step length from baseline (childhood) to follow-up (adolescence).

Outcome: Distance mean difference	R ²	B	SE B	β	t	p
Step count	0.85	0.72	0.02	0.90	37.38	<0.001
Step length (m)	0.13	10074.67	675.71	0.36	14.91	<0.001

R²: R-squared; B: unstandardized beta; SE B: standard error for the unstandardized beta; β : standardized beta; t: t-test statistic; p: probability value.

incorporating the increased step length improved our understanding of these changes. Recommendations for daily ambulatory distance for children and adolescents should be considered in addition to step count recommendations with the knowledge that step length increases with age.

Author statement

RFG: Data curation; formal analysis, writing, including editing; KJJ: Conceptualization, writing and data curation; RR: Analysis, writing and review; MH: Funding acquisition, project administration and review; TAB: project administration and review; MEM: Funding acquisition, project administration, supervision and review.

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Declaration of competing interest

No conflict of interest to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jesf.2020.08.001>.

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