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## Gross Motor Competence and Peak Height Velocity in 10- to 14-Year-Old Canadian Youth: A Longitudinal Study

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### ABSTRACT

The objective of this study was to evaluate gross motor competence and growth spurt in Canadian youth. Eighty-two children (38 boys, 44 girls) were assessed over a time period of five years. Growth rate was measured quarterly; motor competence was evaluated once per year using the Bruininks-Oseretsky Test of Motor Proficiency. Peak height velocity (PHV) occurred at a significantly younger age in the girls ( $11.3 \pm 0.4$  years) than the boys ( $13.4 \pm 0.3$  years;  $p < .001$ ), and growth rate during PHV was significantly greater in the boys than the girls ( $2.8 \pm 1.3$  vs.  $2.0 \pm 0.7$  cm/quarter;  $p = .003$ ). Gross motor competence outcomes were significantly above the North American normative scores ( $p < .05$ ) over the measured time period. After the occurrence of PHV, strength, strength/agility, and gross motor skill significantly decreased in girls ( $p < .01$ ), and running speed/agility significantly decreased in boys ( $p < .05$ ). This finding emphasizes that motor competence in pre-adolescent children may suddenly decrease after their growth spurt.

### KEYWORDS

Peak height velocity;  
physical education;  
bruininks-oseretsky test;  
motor skill proficiency

### Purpose

The development of motor competence (i.e., motor proficiency, motor performance, fundamental movement/motor skill, motor ability, and motor coordination (Robinson et al., 2015) in children and youth is an important step for athleticism, cognitive ability (Davis, Pitchford, & Limback, 2011), psychosocial health (Lees & Hopkins, 2013), and daily living (Deforche et al., 2009), and can and should be learned and practiced (Logan, Robinson, Wilson, & Lucas, 2012; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Motor competence is also an important factor for cardiorespiratory and musculoskeletal fitness (Cattuzzo et al., 2016; Lubans et al., 2010), healthy weight status (Cattuzzo et al., 2016; Lubans et al., 2010), and physical activity levels (Bremer & Lloyd, 2014; Holfelder & Schott, 2014; Logan, Webster, Getchell, Pfeiffer, & Robinson, 2015; Lubans et al., 2010).

Physical education (PE), as part of the required school curriculum may not be sufficient for children to acquire basic motor competence (McKenzie et al., 2001), especially when considering that little emphasis is placed on quality and quantity of PE (Canadian Fitness & Lifestyle Research Institute, 2012). Research on school PE and community-based programs to promote physical activity have shown mixed evidence on the development of motor competence in children and youth (Dobbins, De Corby,

Robeson, Husson, & Tirilis, 2009; Kriemler et al., 2011; Morgan et al., 2013). Critiques of these studies include the use of non-validated measures, short intervention periods, and a focus on classes taught by non-PE specialists (Dobbins et al., 2009; Kriemler et al., 2011). It is therefore unclear how long-term PE interventions delivered by PE-specialists affect the development of gross motor competence in children.

The impact that sex may have on the pre-adolescent development of motor competence is not conclusive. While boys typically have greater object control (i.e. object manipulation, such as throwing, catching, or kicking a ball) than girls (Barnett, Morgan, van Beurden, & Beard, 2008; LeGear et al., 2012), it is unclear whether sex differences for locomotor skills such as hop, side gallop, and vertical jump are present (Barnett et al., 2008; Hardy, King, Farrell, Macniven, & Howlett, 2010; Robinson, 2011) or not (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Okely, Booth, & Chey, 2004). It also needs to be considered that pre-adolescent sex differences may be a result of social determinants, as boys typically have greater perceived motor competence than girls (Masci, Schmidt, Marchetti, Vannozzi, & Pesce, 2016; Piek, Baynam, & Barrett, 2006).

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Development of gross motor competence can also be affected by rate of maturation. As an example, motor competence of children aged 7–12 years were found to be influenced to a higher degree by their skeletal ages than their body mass (Katzmarzyk, Malina, & Beunen, 1997). Girls typically experience their growth spurt at a younger age than boys (Frisch & Revelle, 1971), and as a result, may score higher in motor competence tests in the subsequent year(s) (Foulkes et al., 2015). However, a growth spurt may have temporary negative effects on coordination, and a drop in motor competence may occur after experiencing a major growth spurt (Bisi & Stagni, 2016).

The aim of this study was to explore how the adolescent growth spurt affects gross motor competence in male and female youth. A further goal was to evaluate the development of gross motor competence in typically developing Canadian youth who participate in a quality school PE program over a time period of 5 years, and to compare it to the North American normative scores for children with the same age and sex. Based on previous studies, it was hypothesized that (1) there would be a temporary decrease in motor competence after a sudden increase in height, that (2) the girls would have relatively better motor competence than the boys, due to earlier maturation, and that (3) the youth would show significantly higher motor competence outcomes than the North American normative scores due to their participation in a quality school PE program.

## Method

### Participants

Participants were school children in Calgary, Alberta, Canada born between March 2000 and December 2002. They were all in fourth grade at the time of enrollment and moved from the elementary school into the same publicly funded middle school for fifth grade. One hundred and eleven school children were enrolled into the study. Twenty-nine subjects were excluded from the dataset as they missed more than 50% of the assessments throughout the 5-year study. Therefore, a total of 82 school children (38 boys, 44 girls) were included in data analysis, whereas 1 girl missed the assessments in 2014, and another girl and a boy were not able to participate in 2015 (Table 1).

The participants were tracked over 5 years while attending two different schools. While at the elementary school (grade 4), all students received 30 min of co-educated daily PE from a content specialist. Class size was approximately 20–24 students. In middle school (grades 5–8), all students attended a daily co-

educated physical activity experience consisting of a combination of structured 50-min PE one day, and a homeroom teacher-led 30-min physical activity experience on alternate days. Class size was about 25–30 students. All study participants attended the PE classes as offered by the respective schools.

For each child, one parent or guardian gave written informed consent to participate in this study. Verbal assent was received from each participant on an annual basis. The Human Research Ethics Board at Mount Royal University approved this project (MRU-101079). All procedures were conducted in agreement with the principles expressed in the Declaration of Helsinki.

### Procedure

The data collection was led by a qualified Research Coordinator with several years of training and experience using the motor competence assessment tools. Research Assistants were trained and monitored throughout the project by the Research Coordinator. The motor competence testing took place in a dedicated location such as an empty classroom or vacant gymnasium stage. The motor competence testing for each student took approximately 30 min whereas height and weight measurements took approximately 5 min. The PE teachers who instructed the students were all discipline specialists. All data were verified by an independent research assistant unrelated to the collection of data, whereas an error rate of less than 1% (0.62%) was noted. Corrections were made to the data when necessary during the verification process.

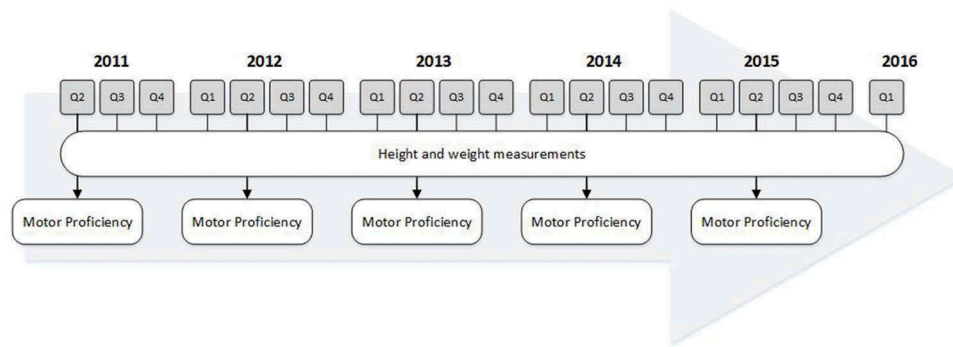
### Growth data

Growth data (height and weight) were collected quarterly by the research team starting in the second quarter of 2011 and ending in the first quarter of 2016 (Figure 1). The first quarter corresponded to March of the respective year, the second quarter was in May, the third quarter in September, and the last quarter in December. Standing height was measured using a portable stadiometer (Seca 213), and body weight was determined using a children's digital weight scale (Tanita BF 689). Height and weight were both measured while the participants were wearing socks and their regular school PE attire. Body mass index (BMI) was calculated using a commercially available app (BMI Percentile Calculator for Child and Teen, Centers for Disease Control and Prevention, Division of Nutrition, Physical Activity, and Obesity) accounting for the participants' age and sex, and was then converted to BMI percentiles.

**Table 1.** Anthropometric data of boys and girls from 2011 to 2015.

Year-Quarter	Grade	N		Age (years)		Height (cm)		Weight (kg)		BMI (Percentile)	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
2011-Q2	4	38	44	10.1 ± 0.3	9.9 ± 0.4	139.9 ± 7.1	138.0 ± 6.4	35.5 ± 7.6	33.7 ± 7.2	42.5 ± 32.4	36.0 ± 28.1
2012-Q2	5	38	44	11.1 ± 0.3	10.9 ± 0.4	146.2 ± 7.1	145.7 ± 7.0	40.3 ± 8.6	39.5 ± 9.3	58.7 ± 31.1	56.2 ± 30.4
2013-Q2	6	38	44	12.1 ± 0.3	11.9 ± 0.4	152.7 ± 7.5	152.5 ± 6.8	45.2 ± 9.7	45.3 ± 10.6	49.4 ± 32.7	50.0 ± 28.8
2014-Q2	7	38	43	13.1 ± 0.3	12.9 ± 0.4	159.3 ± 8.0	157.2 ± 6.0	51.5 ± 11.4	50.6 ± 10.4	54.3 ± 33.8	55.1 ± 27.0
2015-Q2	8	37	42	14.1 ± 0.3	13.9 ± 0.4	166.6 ± 7.0*	160.0 ± 5.5	58.0 ± 9.5	54.4 ± 9.1	53.4 ± 31.5	58.0 ± 26.3

BMI = Body mass index, \*Boys> Girls ( $p < .001$ ). Note that one girl missed the assessments in 2014, and another girl and boy missed the assessments in 2015.



**Figure 1.** Overview of quarterly (Q) growth and yearly motor proficiency data collection time points.

### **Motor competence**

Motor competence was assessed in the second quarter of every year between 2011 and 2015 (Figure 1) using the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2). Subtests including bilateral coordination, balance, running speed/agility, and strength, as well as composites consisting of body coordination, strength/agility, and gross motor skill were assessed (Bruininks & Bruininks, 2005). Testing procedures and instructions precisely followed the administration protocol described in the BOT-2 manual (Bruininks & Bruininks, 2005).

**Bilateral coordination.** Bilateral coordination was tested using seven different exercises: (1) touching nose with index fingers with eyes closed [number of touches], (2) jumping jacks [number of jumping jacks], (3) jumping in place with same sides synchronized [number of jumps], (4) jumping in place with opposites sides synchronized [number of jumps], (5) pivoting thumbs and index fingers [number of pivots], (6) tapping feet and fingers with same sides synchronized [number of taps], and (7) tapping feet and fingers with opposite sides synchronized [number of taps]. Each participant performed two trials. The higher score out of the two trials was transformed into a point score for each subtest. Point scores from all subtests were added up to generate the total point score for bilateral coordination.

**Balance.** Balance was tested through nine different exercises: (1) standing with feet apart on a line with eyes open for maximum 10 sec [seconds], (2) walking forward on a line [number of steps], (3) standing on one leg on a line with eyes open for maximum 10 sec [seconds], (4) standing with feet apart on a line with eyes closed for maximum 10 sec [seconds], (5) walking forward heel-to-toe on a line [number of steps], (6) standing on one leg on a line with eyes

closed for 10 sec [seconds], (7) standing on one leg on a balance beam with eyes open for 10 sec [seconds], (8) standing heel-to-toe on a balance beam for 10 sec [seconds], and (9) standing on one leg on a balance beam with eyes closed for 10 sec [seconds]. Each participant performed two trials, unless the maximum score was achieved on the first trial. The better of the two raw scores was then converted into a point score for each exercise. Point scores from each skill were summed to generate the total point score for balance.

**Running speed/agility.** Assessment of running speed/agility included five different exercises: (1) shuttle run [seconds], (2) stepping sideways over a balance beam for 15 sec [number of steps], (3) one-legged stationary hop for 15 sec [number of hops], (4) one-legged side hop for 15 sec [number of hops], and (5) two-legged side hop for 15 sec [number of hops]. Participants were only given a second trial if they stumbled or fell during the first trial. The raw scores were then converted into point scores and summed to generate the total point score for running speed/agility.

**Strength.** Strength was measured using five different exercises: (1) standing long jump [inches], (2) knee push-ups or full push-ups for 30 sec [number], (3) sit-ups for 30 sec [number], (4) wall sit for maximum 60 sec [seconds], and (5) v-up for maximum 60 sec [seconds]. Participants were allowed a second trial for the standing long jump if they stumbled or fell during the first trial. The raw scores were converted into point scores and summed into the total point score for strength.

Using the BOT-2 protocol for scoring, the total point score for each subtest was converted into a scale score, accounting for the participant's sex and age. BOT-2 scale scores have a mean of 15 and a standard deviation of 5. Scale scores range from 1 to 35, where 1 to 5 corresponds to well-below the average, 5 to 10 below

average, 10 to 20 within average, 20 to 25 above average, and 25 to 35 well-above average.

The scale scores of the subtests were then used to calculate the BOT-2 composite scores for body coordination (the sum of the bilateral coordination and the balance scale scores), strength/agility (the sum of the running speed/agility and the strength scale scores), and gross motor skill (the sum of all four subtest scale scores). The resulting composite scores were then converted into standard scores by using the performance measures of a reference group with the same sex and age range as the study participants. BOT-2 composite scores range from 20 to 80, have a mean of 50, and a standard deviation of 10. Standard scores of 20 to 30 correspond to well-below the average, 30 to 40 is below average, 40 to 60 is within average, 60 to 70 is above average, and 70 to 80 is well-above average.

### Statistical analysis

All statistical procedures were performed using IBM SPSS software (version 20, Chicago, Illinois). Normal distribution of the growth rate and motor competence data was checked using the Shapiro-Wilk test, which provided evidence of a normal distribution ( $p > .05$ ) for all variables and for boys and girls. Descriptive statistics (mean  $\pm$  standard deviation) were calculated by sex for age, height, weight, and BMI. Growth rate was determined each quarter by calculating the height difference between two neighboring quarters (e.g., height 2011-Q3 – height 2011-Q2). Peak height velocity (PHV) was defined by the highest growth rate for each individual, and the corresponding age was determined as age of PHV. Unpaired  $t$ -tests (two-tailed) were performed to compare anthropometric and growth rate data between boys and girls. To determine motor competence, mean values and standard deviations (SD) were calculated for all scale scores, composite scores, and the gross motor skill score, and were reported for boys and girls separately. Data were compared to the North American normative scores using a one-sample  $t$ -test. In order to compare motor competence outcomes over the test period and between the boys and girls, a two-way repeated measures analysis of variance (ANOVA) with 5 (year)  $\times$  7 (test) and sex as between-subjects factor was computed. In case of significant interactions, Bonferroni adjusted post-hoc analyses were performed. The level of significance was set at  $\alpha = 0.05$ .

## Results

### Anthropometric data

Anthropometric characteristics of the participants are described in Table 1. Height, weight, and BMI were

comparable between the boys and girls, with the exception of height in 2015, as the boys were significantly taller than the girls ( $166.6 \pm 7.0$  cm vs.  $160.0 \pm 5.5$  cm,  $p < .001$ ). Out of the assessed participants, 14 out of 82 (17.1%) were overweight or obese.

### Peak height velocity

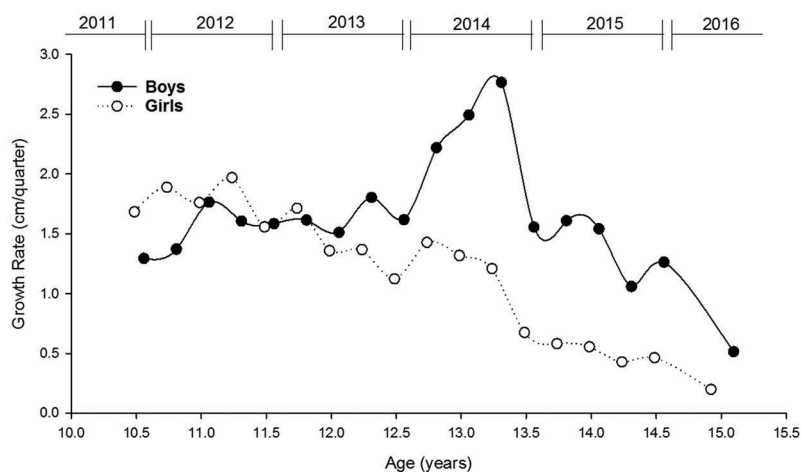
PHV occurred at a significantly younger age ( $p < .001$ ) in the girls ( $11.3 \pm 0.4$  years) than the boys ( $13.4 \pm 0.3$  years); however, the growth rate during PHV was significantly greater in the boys ( $p = .003$ ) with height increases of  $2.8 \pm 1.3$  cm/quarter as compared to the girls ( $2.0 \pm 0.7$  cm/quarter). Boys showed the largest weight gains of 2.95 kg/quarter at the age of  $13.4 \pm 0.3$  years; no clear peak was found for the girls as they showed consistent weight gain throughout the study. Figure 2 displays the quarterly growth rate in height by age for the boys and girls who participated in the study.

### Motor competence

Motor competence outcomes (mean  $\pm$  SD) were within the average range for the sub scores, composite scores, and gross motor skill score. Scores are considered within the average range if they are between 10 and 20 for the sub scores, and 40 and 60 for the composite scores. However, the calculated mean of the boys and girls was generally above the mean of North American normative scores, which was statistically ( $p < .05$ ) confirmed over the 5 years for bilateral coordination, running speed/agility, strength/agility, and gross motor skill (Table 2).

The repeated measures ANOVA showed significant main effects for the type of motor competence test ( $F(6,450) = 3758.729$ ,  $p < .001$ ) and for testing year ( $F(4,300) = 4.395$ ,  $p = .002$ ), and non-significant main effects for sex ( $F(1,75) = 0.822$ ,  $p = .368$ ). Significant interaction effects were only found between test and year ( $F(24,1800) = 3.421$ ,  $p < .001$ ). Significant post-hoc outcomes were found in several test items. Balance significantly decreased from year 2011 to 2012 ( $p = .008$ ), and running speed/agility significantly decreased from year 2014 to 2015 ( $p = .022$ ). Strength significantly decreased from 2011 to 2013 ( $p = .001$ ) and to 2014 ( $p = .012$ ), and significantly increased from 2014 to 2015 ( $p = .041$ ). Body coordination significantly decreased from 2011 to 2012 ( $p = .021$ ) and significantly increased from 2012 to 2014 ( $p = .034$ ). Strength/agility and gross motor skill both significantly decreased from 2011 to 2013 ( $p = .007$  and  $p = .008$ , respectively).





**Figure 2.** Quarterly growth rate in height by age for the boys and girls ( $N = 82$ ). Boys reached their peak height velocity (PHV) at the average age of  $13.4 \pm 0.3$  years; girls reached their PHV at the average age of  $11.3 \pm 0.4$  years.

**Table 2.** Mean and standard deviation (SD) of motor competence outcomes for the boys and girls assessed in this study.

		Boys		Composites	Boys		Composites	Boys		Boys	Girls
Sub scores		Scale Score Mean (SD)	Scale Score Mean (SD)		Score Mean (SD)	Score Mean (SD)		Score Mean (SD)	Score Mean (SD)		
2011	Bilateral Coordination	<b>17.5 (2.8)</b>	<b>16.4 (3.7)</b>	Body Coordination	<b>53.6 (8.2)</b>	<b>57.7 (6.4)</b>	Gross Motor Skill	<b>58.5 (8.4)</b>	<b>56.9 (7.2)</b>		
	Balance	<b>17.7 (5.2)</b>	<b>16.6 (3.8)</b>								
	Running Speed/Agility	<b>18.3 (3.0)</b>	<b>19.3 (2.6)</b>	Strength/Agility	<b>57.0 (9.0)</b>	<b>56.3 (7.4)</b>					
	Strength	<b>16.9 (3.3)</b>	<b>17.3 (2.8)</b>								
2012	Bilateral Coordination	<b>16.2 (3.6)</b>	<b>17.5 (3.0)</b>	Body Coordination	51.4 (8.3)	51.2 (8.4)	Gross Motor Skill	<b>53.6 (9.4)</b>	<b>56.0 (8.4)</b>		
	Balance	15.2 (4.4)	14.3 (4.7)								
	Running Speed/Agility	<b>17.6 (2.9)</b>	<b>19.8 (3.0)</b>	Strength/Agility	<b>53.8 (7.2)</b>	<b>56.3 (6.5)</b>					
	Strength	15.7 (3.9)	<b>16.7 (3.3)</b>								
2013	Bilateral Coordination	<b>16.4 (3.3)</b>	<b>17.0 (3.3)</b>	Body Coordination	51.9 (9.3)	52.2 (7.8)	Gross Motor Skill	<b>53.7 (9.5)</b>	<b>54.4 (7.3)</b>		
	Balance	15.2 (4.8)	15.0 (4.3)								
	Running Speed/Agility	<b>18.1 (3.6)</b>	<b>18.7 (3.0)</b>	Strength/Agility	<b>53.6 (7.3)</b>	<b>54.8 (6.4)</b>					
	Strength	15.1 (3.7)	15.8 (3.3)								
2014	Bilateral Coordination	<b>17.4 (2.6)</b>	<b>17.5 (2.9)</b>	Body Coordination	<b>53.7 (8.8)</b>	<b>55.3 (7.7)</b>	Gross Motor Skill	<b>54.1 (8.3)</b>	<b>56.6 (6.5)</b>		
	Balance	15.3 (4.7)	15.8 (4.3)								
	Running Speed/Agility	<b>17.9 (3.1)</b>	<b>19.7 (2.4)</b>	Strength/Agility	<b>53.4 (5.9)</b>	<b>57.4 (5.5)</b>					
	Strength	14.8 (3.1)	<b>16.5 (3.0)</b>								
2015	Bilateral Coordination	<b>17.3 (2.1)</b>	<b>17.8 (2.6)</b>	Body Coordination	<b>53.2 (8.1)</b>	<b>55.1 (7.7)</b>	Gross Motor Skill	<b>54.4 (7.7)</b>	<b>55.9 (5.9)</b>		
	Balance	15.2 (4.6)	15.2 (4.1)								
	Running Speed/Agility	<b>17.5 (2.2)</b>	<b>18.2 (2.1)</b>	Strength/Agility	<b>53.6 (5.7)</b>	<b>56.2 (5.2)</b>					
	Strength	15.8 (3.2)	<b>17.2 (3.2)</b>								

SD = Standard Deviation. Numbers printed in **bold** are significantly above the mean of the North American normative scores ( $p < .05$ ). The North American norms are  $15 \pm 5$  for the sub scores and  $50 \pm 10$  for the composite scores.

## Discussion

This study assessed growth rate using PHV and motor competence using the BOT-2 (Bruininks & Bruininks, 2005) in Canadian youth over 5 years. Outcomes on growth rate showed that the girls experienced their PHV at a significantly younger age than the boys and that the boys showed significantly larger height increases during PHV than the girls. Motor competence outcomes of the boys and girls were comparable and many were significantly above the North American normative scores published in the BOT-2 manual (Bruininks & Bruininks, 2005). Lastly, it was found that certain motor competence scores significantly decreased after the occurrence of PHV.

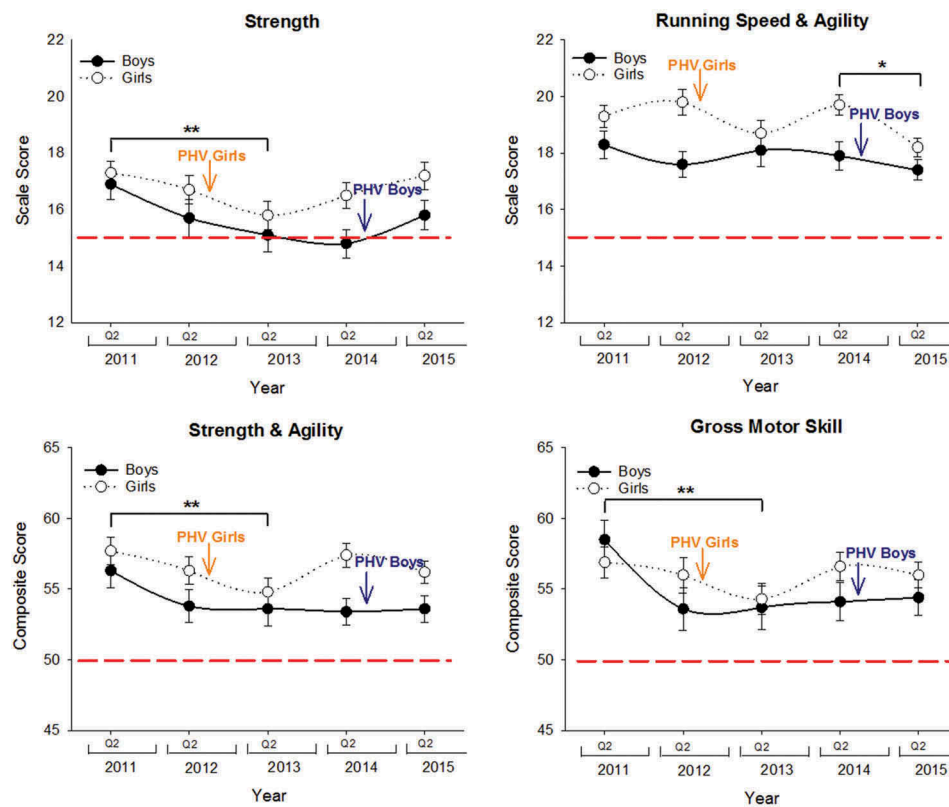
The association between PHV and motor competence has been widely discussed in the literature and generally states that motor competence in youth typically decreases immediately after the occurrence of PHV and recovers in the following year(s) (Beunen & Malina, 1988; Bisi & Stagni, 2016; Johnston, 1982). This was confirmed in the present study for some, but not all, motor competence outcomes, which partially confirms our first hypothesis. Interestingly, this effect was more prevalent in the girls even though the boys experienced a significantly greater sudden increase in height during their growth spurt. Strength, strength/agility, and gross motor skill significantly decreased from 2011 to 2013 in the girls which aligns with their PHV that occurred in the third quarter of 2012

(Figure 3). However, the sudden decrease in motor competence was recovered in the subsequent year. The boys experienced PHV in the third quarter of 2014, and running speed/agility significantly decreased from pre- to post-occurrence of PHV. Further trends in the development of motor competence after the boys experienced PHV is unclear, as no motor skill data were captured after 2015, which poses a limitation to the study. Similarly, we may have missed PHV in earlier maturing girls and later maturing boys due to the time frame of data collection. This may have introduced an error, especially considering that the approach to estimate age at PHV was not optimal. Future studies examining this topic are advised to use more sophisticated modelling techniques for the calculation of age at PHV. Another limitation to this study is that motor competence was only assessed once each year, meaning that we may have missed subtleties and/or further effects of PHV on motor competence.

Although the girls experienced their growth spurt at a significantly earlier age than the boys, their relative motor competence did not exceed the boys' in the following year. This goes against our second hypothesis, which stated that

girls would have better relative motor competence than the boys due to earlier maturation (Barnett et al., 2010; Okely et al., 2004). However, because the BOT-2 adjusts motor competence scale scores for sex and age, absolute differences between the boys and girls may have been present before adjusting the scores for sex. Previous studies investigating sex differences in motor competence reported that boys showed higher object control skills than girls (Barnett et al., 2010; Okely et al., 2004); however, object control was not assessed in the present study and is therefore a limitation.

Scores on four out of the seven motor competence measures (bilateral coordination, running speed/agility, strength/agility, and gross motor skill) were consistently higher than the North American normative scores over the period of the study, which partially confirms our third hypothesis, which stated that the Canadian youth in our sample would demonstrate significantly better motor competence than the North American normative scores. Although it is unclear how school PE programs need to be designed and delivered to promote the development of motor competence in children and youth (Dobbins et al., 2009; Kriemler et al., 2011), quality PE experiences at high



**Figure 3.** Peak height velocity (PHV) and motor competence in boys and girls. Strength, strength/agility, and gross motor skill significantly ( $**p < .01$ ) decreased from 2011 to 2013 after the occurrence of PHV in girls; running speed/agility significantly ( $*p < .05$ ) decreased from 2014 to 2015 after the occurrence of PHV in boys. Note that the arrows indicate PHV at the age of  $13.4 \pm 0.3$  years for the boys and at the age of  $11.3 \pm 0.4$  years for the girls. The dashed line represents the North American normative scores.



frequencies (Dallolio, Ceciliani, Sanna, Garulli, & Leoni, 2016) and over multiple years (Chen, Hammond-Bennett, & Hynar, 2017) have been shown to increase children's motor competence, especially when delivered by a specialist PE teacher (Gallotta et al., 2017). While attending elementary school (grades 1–4), the students received daily PE from a subject specialist. The participants in this study attended a public middle school that offers daily physical activity experiences. During middle school, the students experienced between 30 and 50 minutes of daily physical activity including PE instruction from a PE specialist on alternating days. Although causality cannot be inferred, it can be speculated that participants achieved higher motor competence scores than their comparator population because of their participation in high quality and quantity school-based PE opportunities.

However, it must be considered that the quality of the PE program was not evaluated, that the present sample size was relatively small ( $N = 82$ ) after a 26% attrition rate due to missed assessments, and that the outcomes were compared to the North American normative scores from the BOT-2 manual (Bruininks & Bruininks, 2005) and not to a randomized controlled group. Future studies are advised to investigate how PE programs delivered by a specialist PE teacher affect motor competence in youth, with comparison to a representative control group. Development of motor competence does not have to be limited to the children's PE program; parents can also facilitate physical skill development. As an example, family-focused community based programs (Bronikowski et al., 2016) as well as after school extracurricular physical activity programs (Silva Batista, Almeida Honorio, Jones, Matos Serrano, & Duarte Petrica, 2017) have shown to enhance general coordinative ability in children.

Physical skills of children and adolescents are also known to be negatively affected by excessive BMI (Bryant, Duncan, & Birch, 2014; Castetbon & Andreyeva, 2012; Cliff et al., 2012; Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012). Data from 2,530,100 Canadian children aged 5 to 11 years state that 27.6% were overweight or obese in 2015 (Statistics Canada, 2015). Provincial data reported similar rates in Albertan children with 29.9% being overweight or obese (Statistics Canada, 2015). The Albertan youth in the present study showed overweight and obesity rates of 17%, which were slightly lower than provincial and national averages. It is therefore possible that participants in the present study had higher motor competence scores because there were fewer overweight and obese children as compared to average Canadian youth.

## Conclusion

Gross motor skill testing using the BOT-2 (Bruininks & Bruininks, 2005) provided some evidence that the boys' and girls' motor competence may decrease after the occurrence of PHV and recover in the following year (s). Coaches, parents, and teachers are advised to be mindful of their expectations when working with pre-adolescent children, as their motor competence may suddenly decrease after their growth spurt; the focus may need to be shifted to alternative outcomes such as cardiovascular performance or flexibility. Another outcome of this study was that the participants showed motor competence that was above the average in many areas of motor competence development compared to the North American normative scores published in the BOT-2 manual. The study participants were all attending a middle school that offers daily physical activity partially delivered by a specialist PE teacher, which may have contributed to their higher motor competence scores. However, quality of the PE program was not assessed in this study, and future research should focus on the effect of school-based quality PE programs on the development of motor competence in children.

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## References

- Barnett, L. M., Morgan, P. J., van Beurden, E., & Beard, J. R. (2008). Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: A longitudinal assessment. *International Journal of Behavioral Nutrition and Physical Activity*, 5. doi:10.1186/1479-5868-5-29
- Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2010). Gender differences in motor skill proficiency from childhood to adolescence: A longitudinal study. *Research Quarterly for Exercise and Sport*, 81(2), 162–170. doi:10.1080/02701367.2010.10599663
- Beunen, G., & Malina, R. M. (1988). Growth and physical performance relative to the timing of the adolescent spurt. *Exercise and Sport Sciences Reviews*, 16, 503–540.
- Bisi, M. C., & Stagni, R. (2016). Development of gait motor control: What happens after a sudden increase in height during adolescence? *BioMedical Engineering Online*, 15(1), 47. doi:10.1186/s12938-016-0159-0
- Bremer, E., & Lloyd, M. (2014). The importance of fundamental movement skill proficiency for physical activity in elementary school age females. *Revue phénEPS/PHEnex Journal*, 6(2), 1–12.
- Bronikowski, M., Bronikowska, M., Pluta, B., Maciaszek, J., Tomczak, M., & Glapa, A. (2016). Positive impact on physical activity and health behaviour changes of a 15-week family focused intervention program: “Juniors for seniors”. *BioMed Research International*, 2016, 5489348. doi:10.1155/2016/5489348
- Bruininks, R., & Bruininks, B. (2005). *Bruininks-Oseretsky Test of motor proficiency (BOT-2)* (2nd ed.). Minneapolis, MN: Pearson Assessment.
- Bryant, E. S., Duncan, M. J., & Birch, S. L. (2014). Fundamental movement skills and weight status in British primary school children. *European Journal of Sport Science*, 14(7), 730–736. doi:10.1080/17461391.2013.870232
- Canadian Fitness & Lifestyle Research Institute. (2012). *Encouraging active schools: 2011 opportunities for physical activity at school survey*. Retrieved October 12, 2017 from Ottawa, ON <http://www.cflri.ca/sites/default/files/node/1054/files/Schools%202011%20Bulletin%2012%20-362%20Policy%20EN.pdf>
- Castetbon, K., & Andreyeva, T. (2012). Obesity and motor skills among 4 to 6-year-old children in the United States: Nationally-representative surveys. *Bmc Pediatrics*, 12. doi:10.1186/1471-2431-12-34
- Cattuzzo, M. T., Henrique, R. D., Re, A. H. N., de Oliveira, I. S., Melo, B. M., Moura, M. D., ... Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science and Medicine in Sport*, 19(2), 123–129. doi:10.1016/j.jsams.2014.12.004
- Chen, W., Hammond-Bennett, A., & Hypnar, A. (2017). Examination of motor skill competency in students: Evidence-based physical education curriculum. *BMC Public Health*, 17(1), 222. doi:10.1186/s12889-017-4105-2
- Cliff, D. P., Okely, A. D., Morgan, P. J., Jones, R. A., Steele, J. R., & Baur, L. A. (2012). Proficiency deficiency: Mastery of fundamental movement skills and skill components in overweight and obese children. *Obesity*, 20(5), 1024–1033. doi:10.1038/oby.2011.241
- Dallolio, L., Cecilian, A., Sanna, T., Garulli, A., & Leoni, E. (2016). Proposal for an enhanced physical education program in the primary school: Evaluation of feasibility and effectiveness in improving physical skills and fitness. *Journal of Physical Activity & Health*, 13(10), 1025–1034. doi:10.1123/jpah.2015-0694
- Davis, E. E., Pitchford, N. J., & Limback, E. (2011). The interrelation between cognitive and motor development in typically developing children aged 4–11 years is underpinned by visual processing and fine manual control. *British Journal of Psychology*, 102(3), 569–584. doi:10.1111/j.2044-8295.2011.02018.x
- Deforche, B. I., Hills, A. P., Worringham, C. J., Davies, P. S., Murphy, A. J., Bouckaert, J. J., & De Bourdeaudhuij, I. M. (2009). Balance and postural skills in normal-weight and overweight prepubertal boys. *International Journal of Pediatric Obesity*, 4(3), 175–182. doi:10.1080/17477160802468470
- Dobbins, M., De Corby, K., Robeson, P., Husson, H., & Tirilis, D. (2009). School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6–18. *Cochrane Database of Systematic Reviews*, (1), CD007651.
- Foulkes, J. D., Knowles, Z., Fairclough, S. J., Stratton, G., O'Dwyer, M., Ridgers, N. D., & Fowweather, L. (2015). Fundamental movement skills of preschool children in Northwest England. *Perceptual and Motor Skills*, 121(1), 260–283. doi:10.2466/10.25.PMS.121c14x0
- Frisch, R. E., & Revelle, R. (1971). The height and weight of girls and boys at the time of initiation of the adolescent growth spurt in height and weight and the relationship to menarche. *Human Biology*, 43(1), 140–159.
- Gallotta, M. C., Emerenziani, G. P., Iazzoni, S., Iasevoli, L., Guidetti, L., & Baldari, C. (2017). Effects of different physical education programmes on children's skill- and health-related outcomes: A pilot randomised controlled trial. *Journal of Sports Sciences*, 35(15), 1547–1555. doi:10.1080/02640414.2016.1225969
- Hardy, L. L., King, L., Farrell, L., Macniven, R., & Howlett, S. (2010). Fundamental movement skills among Australian preschool children. *Journal of Science and Medicine in Sport*, 13(5), 503–508. doi:10.1016/j.jsams.2009.05.010
- Holfelder, B., & Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Psychology of Sport and Exercise*, 15(4), 382–391. doi:10.1016/j.psychsport.2014.03.005
- Johnston, F. E. (1982). Somatic and motor development of Belgian secondary schoolboys - Ostin, M., Simons, J., Beunen, G., Renson, R., Vangerven, D. *American Journal of Physical Anthropology*, 58(4), 464. doi:10.1002/ajpa.1330580417
- Katzmarzyk, P. T., Malina, R. M., & Beunen, G. P. (1997). The contribution of biological maturation to the strength and motor fitness of children. *Annals of Human Biology*, 24(6), 493–505.
- Kriemler, S., Meyer, U., Martin, E., van Sluijs, E. M., Andersen, L. B., & Martin, B. W. (2011). Effect of school-based interventions on physical activity and fitness

- in children and adolescents: A review of reviews and systematic update. *British Journal of Sports Medicine*, 45 (11), 923–930. doi:[10.1136/bjsports-2011-090186](https://doi.org/10.1136/bjsports-2011-090186)
- Lees, C., & Hopkins, J. (2013). Effect of aerobic exercise on cognition, academic achievement, and psychosocial function in children: A systematic review of randomized control trials. *Preventing Chronic Disease*, 10, E174. doi:[10.5888/pcd10.130016](https://doi.org/10.5888/pcd10.130016)
- LeGear, M., Greyling, L., Sloan, E., Bell, R. I., Williams, B. L., Naylor, P. J., & Temple, V. A. (2012). A window of opportunity? Motor skills and perceptions of competence of children in kindergarten. *The International Journal of Behavioral Nutrition and Physical Activity*, 9, 29. doi:[10.1186/1479-5868-9-29](https://doi.org/10.1186/1479-5868-9-29)
- Logan, S. W., Robinson, L. E., Wilson, A. E., & Lucas, W. A. (2012). Getting the fundamentals of movement: A meta-analysis of the effectiveness of motor skill interventions in children. *Child Care Health and Development*, 38(3), 305–315. doi:[10.1111/j.1365-2214.2011.01307.x](https://doi.org/10.1111/j.1365-2214.2011.01307.x)
- Logan, S. W., Webster, E. K., Getchell, N., Pfeiffer, K. A., & Robinson, L. E. (2015). Relationship between fundamental motor skill competence and physical activity during childhood and adolescence: A systematic review. *Human Kinetics Journals*, 4(4), 416–426.
- Lopes, V. P., Stodden, D. F., Bianchi, M. M., Maia, J. A. R., & Rodrigues, L. P. (2012). Correlation between BMI and motor coordination in children. *Journal of Science and Medicine in Sport*, 15(1), 38–43. doi:[10.1016/j.jsams.2011.07.005](https://doi.org/10.1016/j.jsams.2011.07.005)
- Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents review of associated health benefits. *Sports Medicine*, 40(12), 1019–1035. doi:[10.2165/11536850-000000000-00000](https://doi.org/10.2165/11536850-000000000-00000)
- Masci, I., Schmidt, M., Marchetti, R., Vannozzi, G., & Pesce, C. (2016). When children's perceived and actual motor competence mismatch: Sport participation and gender differences. *Journal of Motor Learning and Development*, 1–33.
- McKenzie, T. L., Stone, E. J., Feldman, H. A., Epping, J. N., Yang, M., Strikmiller, P. K., ... Parcel, G. S. (2001). Effects of the CATCH physical education intervention: Teacher type and lesson location. *American Journal of Preventive Medicine*, 21 (2), 101–109.
- Morgan, P. J., Barnett, L. M., Cliff, D. P., Okely, A. D., Scott, H. A., Cohen, K. E., & Lubans, D. R. (2013). Fundamental movement skill interventions in youth: A systematic review and meta-analysis. *Pediatrics*, 132(5), e1361–1383. doi:[10.1542/peds.2013-1167](https://doi.org/10.1542/peds.2013-1167)
- Okely, A. D., Booth, M. L., & Chey, T. (2004). Relationships between body composition and fundamental movement skills among children and adolescents. *Research Quarterly for Exercise and Sport*, 75(3), 238–247. doi:[10.1080/02701367.2004.10609157](https://doi.org/10.1080/02701367.2004.10609157)
- Piek, J. P., Baynam, G. B., & Barrett, N. C. (2006). The relationship between fine and gross motor ability, self-perceptions and self-worth in children and adolescents. *Human Movement Science*, 25(1), 65–75. doi:[10.1016/j.humov.2005.10.011](https://doi.org/10.1016/j.humov.2005.10.011)
- Robinson, L. E. (2011). The relationship between perceived physical competence and fundamental motor skills in pre-school children. *Child Care Health and Development*, 37 (4), 589–596. doi:[10.1111/j.1365-2214.2010.01187.x](https://doi.org/10.1111/j.1365-2214.2010.01187.x)
- Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine*, 45(9), 1273–1284. doi:[10.1007/s40279-015-0351-6](https://doi.org/10.1007/s40279-015-0351-6)
- Silva Batista, M. A., Almeida Honorio, S. A., Jones, G. W., Matos Serrano, J. J., & Duarte Petrica, J. M. (2017). The influence of extra-curricular physical activities in the development of coordination in pre-school children. *Minerva Pediatrica*. doi: [10.23736/S0026-4946.17.04981-7](https://doi.org/10.23736/S0026-4946.17.04981-7)
- Statistics Canada. (2015). *Measured children and youth body mass index (BMI) (World Health Organization classification), by age group and sex, Canada and provinces, Canadian Community Health Survey - Nutrition*. Retrieved on October 12, 2017 from <http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=1052024&p2=33>