NRC Research Press

ARTICLE

Tracking of physical activity and fitness during the early years

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Abstract: The early years are characterized by rapid physical growth and the development of behaviours such as physical activity. The objectives of this study were to assess the 12-month changes in and the tracking of physical activity and fitness in 400 preschoolers (201 boys, 4.5 ± 0.9 years of age). Physical activity data, expressed as minutes per day and as the percentage of time spent at various intensities while wearing an accelerometer, were collected in 3-s epochs for 7 days. Short-term muscle power, assessed with a 10-s modified Wingate Anaerobic Test, was expressed as absolute (W) and relative (W/kg) peak power (PP) and mean power (MP). Aerobic fitness, assessed with the Bruce Protocol progressive treadmill test, was expressed as maximal treadmill time and heart rate recovery (HRR). Light physical activity decreased by 3.2 min/day ($p < 0.05$), whereas vigorous physical activity increased by 3.7 min/day ($p < 0.001$), from year 1 to year 2. Physical activity exhibited moderate tracking on the basis of Spearman correlations ($r = 0.45–0.59$, $p < 0.001$) and fair tracking on the basis of κ statistics (κ = 0.26–0.38). PP and MP increased from year 1 (PP, 94.1 ± 37.3 W; MP, 84.1 ± 30.9 W) to year 2 (PP, 125.6 ± 36.2 W; MP, 112.3 ± 32.2 W) ($p < 0.001$) and tracked moderately to substantially (PP, $r = 0.89$, κ = 0.61; MP, $r = 0.86$, κ = 0.56). Time to exhaustion on the treadmill increased from 9.4 ± 2.3 min to 11.8 ± 2.3 min ($p < 0.001$) and tracked strongly ($r = 0.82$, κ = 0.56). HRR was unchanged at 65 ± 14 beats/min ($p = 0.297$) and tracked fairly ($r = 0.52$, κ = 0.23). The findings indicate that fitness tracks better than physical activity over a 12-month period during the early years.

Key words: physical activity, fitness, exercise, accelerometry, preschooler, heart rate recovery, health, early years, tracking.

Résumé : Les premières années sont caractérisées par une croissance physique rapide et le développement de comportements comme ceux en activité physique. Cette étude a pour objectif de suivre et d'évaluer sur une période de 12 mois les changements en matière d'activité physique et de condition physique chez 400 enfants d'âge préscolaire (201 garçons, 4,5 ± 0,9 ans). Toutes les 3 s durant 7 jours, on mesure l'activité physique au moyen d'un accéléromètre; le résultat est exprimé en minutes par jour et en pourcentage de la durée du port à diverses intensités. On évalue la puissance musculaire à court terme par une modification du test anaérobie de Wingate de 10 s; le résultat est exprimé par la puissance de pointe (« PP ») et la puissance moyenne (« MP ») en valeur absolue (W) et relative (W/kg). On évalue l'aptitude aérobie au moyen du protocole de Bruce, un test d'effort progressif sur tapis roulant; le résultat est exprimé par la durée maximale de course sur tapis roulant et par la fréquence cardiaque de récupération (« HRR »). En 1 an, l'activité physique d'intensité légère diminue de 3,2 min/jour ($p < 0{,}05$) et l'activité physique d'intensité vigoureuse augmente de 3,7 min/jour ($p < 0{,}001$). L'activité physique présente une trajectoire modérée d'après la corrélation de Spearman ($r = 0{,}45–0{,}59$, $p < 0{,}001$) et une juste trajectoire d'après la statistique Kappa (κ = 0,26–0,38). PP et MP augmentent du début de l'année (PP : 94,1 ± 37,3; MP : 84,1 ± 30,9 W) à la fin de l'année (PP : 125,6 ± 36,2; MP : 112,3 ± 32,2 W, $p < 0{,}001$) et présentent une trajectoire de modérée à substantielle (PP : $r = 0{,}89$, κ = 0,61; MP : $r = 0{,}86$, κ = 0,56). Le temps d'épuisement sur tapis roulant augmente de 9,4 ± 2,3 à 11,8 ± 2,3 min ($p < 0{,}001$) et présente une trajectoire forte ($r = 0{,}82$, κ = 0,56). La HRR ne varie pas (65 ± 14 battements/min, $p = 0{,}297$) et présente une trajectoire juste ($r = 0{,}52$, κ = 0,23). D'après ces observations, la condition physique effectue sur une période de 12 mois une meilleure trajectoire que l'activité physique durant les premières années. [Traduit par la Rédaction]

Mots-clés : activité physique, condition physique, exercice physique, accélérométrie, préscolaire, fréquence cardiaque de récupération, santé, premières années, suivi.

Introduction

The early years of life are characterized by rapid growth and development, and this is a period about which we know the least about physical activity and its influence on health outcomes. One assumption might be that young children are habitually "active enough" and, as such, are reaping the health benefits associated with engaging in physical activity (Timmons et al. 2012*a*). However, indicators of cardiovascular and cardiometabolic diseases such as obesity are beginning to manifest in young children. The Canadian Health Measures Survey reported that 16.4% of 3- to 5-year-olds were already overweight or obese (Colley et al. 2013). There is growing evidence that obesity is prevalent in the early years and that most excess weight has been gained by 5 years of age (Gardner et al. 2009). Body mass index (BMI) tracks moderately well; for example, in an Australian longitudinal study, BMI at age 6 years was a good predictor of BMI in adulthood (Magarey et al. 2003). In a sample of young Canadians, about 30% of children were at risk of becoming overweight or obese, even those as young as

Received 26 June 2015. Accepted 2 December 2015.

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 Published at www.nrcresearchpress.com/apnm on 11 January 2016.

2 years old (He and Sutton 2004). The early manifestation of obesity and its strong tracking suggest that lifestyle interventions that target the early years may be warranted to ensure development of healthy weights. Very little is known about the foundation of physical activity and fitness in the early years and whether these characteristics change, or track, during this early development period.

Physical activity has been shown to increase in volume from age 3 years to age 5 years (Cardon and De Bourdeaudhuij 2008; Grontved et al. 2009), and it is highly transitory, characterized by sporadic, intermittent activity (Obeid et al. 2011). Tracking of physical activity, which refers to the stability of physical activity participation over time (Malina 1996), is fair in the early years (Gabel et al. 2011; Jackson et al. 2003; Kelly et al. 2007), suggesting that preschoolers have more variable physical activity levels than do adolescents and adults (Telama et al. 2014). Sedentary behaviour exhibits fair tracking in young Scottish boys and girls (Kelly et al. 2007). There is evidence from cross-sectional studies to suggest that engagement in physical activity decreases with increasing age in the school-age and adolescent years (Colley et al. 2011), but little is known about how physical activity levels change in the early years. Sedentary behaviour is an independent risk factor for cardiometabolic disease indicators in children, independent of physical activity (Saunders et al. 2014). Although the preschool physical activity and sedentary behaviour research fields are growing, little is known about fitness in this age group.

Health-related fitness refers to those characteristics that are most related to health, chronic disease prevention, and health promotion (Caspersen et al. 1985), and cardiorespiratory fitness is more important than physical activity in predicting future cardiovascular disease risk in children and adolescents. (Hurtig-Wennlof et al. 2007). Heart rate recovery (HRR), an indicator of cardiorespiratory fitness, refers to the rate at which the heart rate (HR) returns to resting levels after exercise (Shetler et al. 2001) because of vagal reactivation (Imai et al. 1994). A faster HRR is a marker of good physical fitness (Shetler et al. 2001) and is inversely related to metabolic risk in healthy children (Lin et al. 2008; Simhaee et al. 2013). In our study, HRR and time to exhaustion on a progressive treadmill test were used as measures of aerobic fitness. Short-term muscle power (STMP) refers to the mechanical power that is delivered during intense, brief exercise (Van Praagh and Doré 2002). Preschoolers take part in physical activity in brief, high-intensity bouts (Obeid et al. 2011); therefore, STMP is necessary for young children to facilitate these movements. To our knowledge, associations between STMP and health in the early years have not been investigated. Laboratory-based fitness testing has rarely been conducted with preschoolers. Performance on health-related fitness tests, including aerobic fitness tests on a treadmill and STMP tests on a cycle ergometer, tends to increase from 3 to 6 years of age (Gabel et al. 2011; Cumming et al. 1978; Parizkova 1996). Moderate 1-year tracking has been observed in preschoolers and kindergarten students for performance on STMP tests (Gabel et al. 2011; Nemet et al. 2013); however, to our knowledge, tracking of aerobic fitness in the early years has not been investigated.

Information about changes and tracking of physical activity and fitness in the early years is limited, and this study serves to fill this knowledge gap. It is essential to investigate physical activity and fitness over time to determine if these characteristics are stable in the early years of life or if they are susceptible to change in the years to come. The objectives of this study were to establish the 1-year changes and to investigate the tracking of physical activity, sedentary behaviour, and fitness in 3- to 5-year-olds. It was hypothesized that performance on fitness tests would improve, physical activity participation would increase, and sedentary behaviours would decrease over the 1-year period and that fitness measures would likely exhibit stronger tracking than physical activity and sedentary behaviour measures.

Table 1. Participant characteristics at year 1 (Y1) and year 2 (Y2).

	Year 1 (n = 400)	Year 2 (n = 400)	Change (Y2 – Y1)	95% CI of the change	
				Lower	Upper
Age (y)	4.5±0.9	5.5±0.9	+1.0±0.6***	1.0	1.0
Height (cm)	106.6±7.8	113.5±7.8	+7.0±1.1***	6.9	7.1
Weight (kg)	17.9±3.2	20.3±3.8	+2.3±2.2***	2.3	2.4
BMI (kg/m²)	15.7±1.3	15.6±1.4	−0.8±0.1**	−0.1	−0.02
BMI percentile	52.3±28.5	51.6±28.1	−0.7±1.0	−1.9	0.5
CDC cut-offs					
Normal weight	80.0	78.2	−1.8		
Obese	4.8	4.0	−0.8		
Overweight	10.6	13.5	+2.9		
Underweight	4.6	4.3	−0.3		

Note: Data are presented as means ± SD or %. BMI, body mass index; CDC, Centers for Disease Control and Prevention; CI, confidence interval. **, $p < 0.01$; ***, $p < 0.001$.

Materials and methods

Study design and participants

Participants were part of the Health Outcomes and Physical activity in Preschoolers (HOPP) study, the methodology of which has been described previously (Timmons et al. 2012*b*). The Hamilton Health Sciences–Faculty of Health Sciences Research Ethics Board provided ethical approval for the study. Four hundred nineteen healthy 3-, 4-, and 5-year-olds were enrolled in the HOPP study and completed year 1 assessments; 400 returned to complete year 2 assessments (a 95% retention rate). On average, visits were 12.1 ± 0.7 months apart (range, 10.8–17.2 months), and 97% of visits occurred within 12 ± 1 months. At year 1, 5 participants could not complete the assessments because of developmental or health concerns and were therefore excluded from all analyses. Fourteen participants did not return for year 2 testing for reasons that included family issues, medical issues, and time commitments or because they had moved away or for unknown reasons.

Height and weight

Height and weight were measured using standard procedures (Timmons et al. 2012*b*). BMI was calculated as weight/height² (kg/m²). BMI percentiles, based on sex and age, were calculated on the basis of Centers for Disease Control and Prevention growth charts to classify children as underweight, normal weight, overweight, or obese (Kuczmarski et al. 2002) for descriptive purposes. Participant characteristics are reported in Table 1.

Physical activity

Physical activity was assessed with ActiGraph GT3XE and GT3X+ accelerometers (Pensacola, Fla., USA). The intraclass correlation between counts of these devices was very high (>0.9), and it was acceptable to use both within the same study (Robusto and Trost 2012). The accelerometers were set to record activity counts in 3-s epochs. Participants were fitted with the accelerometer and were instructed to wear it over their right hip during waking hours for 7 days, except during prolonged water activities. Parents were instructed to record in the provided logbook the times the accelerometer was put on and taken off.

The accelerometer data were analyzed with Actilife software (version 6.6.3; ActiGraph). A period was defined as nonwear if the device recorded 60 min or more of continuous zero counts or if the logbook indicated device removal. If less than 60 min of consecutive zero counts were measured and there was no indication in the logbook that the device was removed, this time remained in the analyses and was considered sedentary time.

Only participants who wore the accelerometer for at least 3 days with a minimum wear time (WT) of 10 h per day were included in the analyses. This minimum WT is recommended for children and achieves a reliability coefficient of 0.9 (Rich et al. 2013). Inclusion of a weekend day does not greatly increase the reliability of accelerometer data in children (Rich et al. 2013), but would have decreased our sample size for this measure. Valid accelerometer data were available for 365 participants (87%) in year 1 and for 367 participants (92%) in year 2, which corresponded to 335 participants who had valid accelerometer data (i.e., met the required WT criteria) in both year 1 and year 2 (Table 2). Daily minutes of physical activity and physical activity expressed as a percentage of wear time (%WT) were calculated to determine the volume of physical activity participation. The cut-points for physical activity intensity were based on cut-points that have been validated in healthy 3-to 5-year-old children (Pate et al. 2006). Moderate physical activity (MPA) was defined as 420 counts per 15-s epoch, and vigorous physical activity (VPA) was defined as 842 counts per 15-s epoch. To account for the 3-s epoch used in this study, the Pate cut-points were divided by 5. This is common practice in physical activity research to accommodate different epochs (Nilsson et al. 2002). As such, activity counts were classified as sedentary time if there were <8 counts/3 s, total physical activity (TPA) if there were ≥8 counts/3 s, light physical activity (LPA) if there were ≥8 counts/3 s and <84 counts/3 s, MPA if there were ≥84 counts/3 s and <164 counts/3 s, moderate-to-vigorous physical activity (MVPA) if there were ≥84 counts/3 s, and VPA if there were ≥164 counts/3 s.

Table 2. Physical activity variables at year 1 and year 2.

	Girls	Boys	95% CI of the difference	
			Lower	Upper
Year 1				
Wear time (h/d)	12.0±0.7	12.1±0.7	−0.2	0.0
Sedentary time (min/d)	477.3±45.6	456.2±45.5***	11.7	30.5
TPA (min/d)	242.3±32.5	269.5±37.8***	−34.4	−19.8
LPA (min/d)	154.1±20.5	165.5±22.3***	−15.8	−6.7
MPA (min/d)	50.1±9.0	58.6±10.8***	−10.6	−6.5
VPA (min/d)	38.2±10.8	45.4±13.3***	−9.7	−4.7
MVPA (min/d)	88.2±18.2	104.0±21.9***	−19.9	−11.6
Sedentary time (%WT)	66.3±4.5	62.9±4.9***	2.5	4.4
TPA (%WT)	33.7±4.5	37.2±4.9***	−4.4	−2.5
LPA (%WT)	21.4±2.8	22.8±2.9***	−2.0	−0.8
MPA (%WT)	7.0±1.3	8.1±1.4***	−1.4	−0.8
VPA (%WT)	5.3±1.5	6.3±1.8***	−1.3	−0.6
MVPA (%WT)	23.3±2.6	14.3±2.9***	−2.6	−1.5
Year 2				
Wear time (h/d)	11.9±0.8	12.1±0.7*	−0.3	−0.0
Sedentary time (min/d)	472.8±54.0	457.5±45.0**	5.1	25.5
TPA (min/d)	243.6±36.6	267.7±34.1***	−31.3	−16.8
LPA (min/d)	151.8±21.7	160.8±20.5***	−13.3	−4.7
MPA (min/d)	50.3±9.5	58.6±9.8***	−10.6	−6.5
VPA (min/d)	41.6±12.9	48.4±12.4***	−9.5	−4.3
MVPA (min/d)	91.9±20.7	107.0±20.2***	−19.4	−11.0
Sedentary time (%WT)	65.9±5.1	63.0±4.5***	1.9	3.9
TPA (%WT)	34.1±5.1	36.9±4.6***	−3.9	−1.9
LPA (%WT)	21.2±3.0	22.2±2.8**	−1.6	−0.4
MPA (%WT)	7.0±1.4	8.1±1.3***	−1.3	−0.8
VPA (%WT)	5.8±1.8	6.7±1.7***	−1.2	−0.5
MVPA (%WT)	12.9±2.9	14.8±2.7***	−2.5	−1.3

Note: Data are presented as means ± SD. The p values represent the results of paired t tests conducted for each variable between year 1 and year 2. CI, confidence interval; TPA, total physical activity; LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate-to-vigorous physical activity; %WT, percentage of wear time. *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

Health-related fitness

STMP

STMP was assessed with a 10-s modified Wingate Anaerobic Test (WAnT) and was represented as peak power (PP) and mean power (MP). This modified WAnT has been shown to be reliable (r = 0.83–0.93) in 3- to 5-year-olds (Nguyen et al. 2011). At year 1, 65 children completed the modified WAnT on a calibrated, mechanically braked cycle ergometer (Fleisch-Metabo, Geneva, Switzerland). Because of a change in equipment during the initial phases of the study, all subsequent tests were completed on an electromagnetic braked cycle ergometer (Lode Corival Pediatric, Groningen, the Netherlands). Twenty-eight participants completed assessments on both ergometers, 1 week apart. Paired t tests and Bland–Altman plots were used to assess the differences in PP and MP between the 2 ergometers. No significant differences were observed (mean difference calculated as Lode − Fleisch-Metabo, 1.6 and −1.1 W for PP and MP, respectively; $p > 0.05$), and bias between the ergometers was 1.6 ± 14.4 (limits of agreement, −26.7 to +29.8) for PP and −1.1 ± 13.6 (limits of agreement, −27.8 to +25.6) for MP. As a result, the groups were combined for analyses.

At year 1 and year 2, PP data were available for 378 participants and MP data were available for 343 participants; some participants could not complete the full 10-s test because of an inability to maintain a pedaling cadence of >25 r/min or because of refusal to continue despite verbal encouragement. For participants who could not maintain the pedaling cadence of >25 r/min for the duration of the test, only PP was included in the analyses. First, the participants were asked to pedal as fast as possible, without resistance, for approximately 20 s or until the pedaling speed plateaued, to determine peak pedaling speed (revolutions per minute). After a short rest, the participants were instructed to pedal as fast as they could. When 80% of the peak pedaling speed was attained, the braking force was applied. Braking force was calculated as 4.5% of body weight for the participants who completed the test on the Fleisch-Metabo ergometer and as 0.55 Nm/kg body weight (van Brussel et al. 2007) on the Lode Corival Pediatric ergometer. At this point, the participant was encouraged to keep pedaling as fast as he or she could for 10 s.

Aerobic fitness

Aerobic fitness was assessed with the Bruce Protocol, a progressive treadmill test that increases in speed and grade every 3 min (Bruce et al. 1973). Previous research has shown that children as young as 4 years old can complete this protocol (Cumming et al. 1978; van der Cammen-van Zijp et al. 2010). At the beginning of each visit, participants walked on the treadmill at a comfortable pace to familiarize themselves with the equipment. As a modification from the traditional Bruce Protocol, participants were required to hold the handrails, and a researcher was positioned behind each participant to ensure safety.

Participants were fitted with an HR monitor (Polar Electro, Kempele, Finland) to monitor HR continuously during the test and recovery.

Treadmill time

The test was terminated when a participant was exhausted, could no longer keep up with the speed of the treadmill, showed signs of emotional distress, or refused to continue despite verbal encouragement. Only participants who achieved a maximal HR of ≥180 beats/min (n = 366) were included in the analyses, to ensure that a maximal, or near-maximal, effort was achieved. Reliability of the Bruce Protocol has not been assessed in preschoolers but was highly reproducible (r = 0.94) in children 7 to 13 years old (Cumming et al. 1978).

HRR

On termination of the test, the participants were seated immediately and asked to remain as still as possible for 2 min. The second indicator of aerobic fitness was 60-s HRR, which was calculated as the difference between the maximal HR and the HR 60 s into recovery. Higher values indicate faster recovery and greater aerobic fitness because diminished HRR has been shown to be associated with increased cardiovascular risk factors in adults (Shetler et al. 2001) and youth (Lin et al. 2008; Simhaee et al. 2013). Data for the participants who did not remain seated or calm during the recovery period, on the basis of the observations of the researcher, were excluded. Valid year 1 and year 2 HRR data were available for 358 participants (89.5%).

Statistical analyses

Statistical analyses were carried out with IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, N.Y., USA). All data are presented as means ± SD. Statistical significance was set at $p < 0.05$. Participant characteristics were analyzed separately for year 1 and year 2. Change scores (Δ = year 2 − year 1) were calculated for all variables. Paired t tests were conducted to determine if variables were different between year 1 and year 2; 95% CIs of the changes were also computed. Tracking, the stability of each characteristic, over the 1-year period was analyzed in 2 ways: Spearman rank order correlations and Cohen's κ statistics. Spearman rank order correlations were used to assess individual rank stability between year 1 and year 2. Correlation coefficients of <0.30 were interpreted as low, those of 0.30–0.60 were interpreted as moderate, and those of >0.6 were interpreted as strong (Malina 1996). Participants were also divided into tertiles (n = 3: low, middle, high) for each variable. Cohen's κ statistics were used to assess stability within tertiles over time. κ statistics of 0–0.2 are interpreted as slight, those of 0.2–0.4 as fair, those of 0.4–0.6 as moderate, those of 0.6–0.8 as substantial, and those of 0.8 to <1.0 as almost perfect strengths of agreement (Munoz and Bangdiwala 1997). Spearman correlation coefficients were appropriate to assess individual stability over time. The purpose of using κ statistics was to assess whether the participants should remain in a certain tertile (e.g., low, middle, or high fitness) over time (Malina 1996). Both methods were used because some individual scores were equal or very similar, and tertile statistics allow multiple participants with similar or the same scores to be classified into the same group.

Results

Physical activity

Table 2 displays physical activity variable results for the boys and the girls from year 1 and year 2. Of the valid data, participants wore the accelerometers for 5.6 ± 1.3 days and 12.1 ± 0.7 h/day at year 1 for and 5.9 ± 1.3 days ($p < 0.001$) and 12.0 ± 0.7 h/day at year 2 ($p = 0.921$). The boys consistently displayed greater levels of physical activity, at all intensities, and lower sedentary times than did the girls at both year 1 and year 2. The boys and the girls were combined for analyses of changes and tracking of physical activity because both groups had similar tracking patterns. When combined, TPA was not significantly changed from year 1 to year 2. However, LPA decreased and MPA remained stable, whereas VPA, and consequently MVPA, increased.

Health-related fitness

Table 3 displays the health-related fitness results from year 1 and year 2. At years 1 and 2, the boys displayed greater PP, PP/kg, treadmill time, and HRR than did the girls. At year 2, the boys also displayed greater MP and MP/kg. Tracking of fitness measures was similar between the boys and the girls; therefore, the groups were collapsed for further analyses. On average, PP, MP, PP/kg, and MP/kg increased significantly from year 1 to year 2. Average treadmill time increased significantly. At year 1, the average peak HR achieved during the test was 196 ± 7 beats/min and at year 2, maximal HR was 200 ± 7 beats/min ($p < 0.001$). HRR did not change significantly from year 1 to year 2.

Tracking

The boys and the girls were analyzed together for tracking. The boys were consistently more active and displayed better performance on the fitness tests than did the girls; however, the tracking statistics between the groups were similar. Physical activity, at all intensities, displayed moderate tracking on the basis of Spearman correlations and fair tracking on the basis of κ statistics. Tracking of physical activity was equivalent whether expressed as minutes per day or percentage of WT. With the exception of HRR, the fitness measures displayed stronger tracking than did the physical activity measures (Table 4).

Table 3. Fitness variables at year 1 (Y1) and year 2 (Y2).

	n	Year 1	Year 2	Change (Y2 – Y1)	95% CI of the change: Lower	Upper
PP (W)	378	94.1±37.3	125.6.±36.2	+31.5±71.6***	29.7	33.3
PP/kg (W/kg)	378	5.1±1.4	6.1±0.9	1.0±1.0***	0.9	1.1
MP (W)	343	84.1±30.9	112.3±32.3	+28.2±16.4***	26.5	29.9
MP/kg (W/kg)	343	4.5±1.2	5.4±0.85	0.9±0.9***	0.8	1.0
Treadmill time (min)	366	9.4±2.3	11.8±2.3	+2.4±1.4***	2.3	2.6
HRR (beats/min)	358	65±14	65±14	−0.8±14.0	−2.2	0.7

Note: Data are presented as means ± SD for absolute (W) and relative (W/kg) intensities. The p values represent the results of paired t tests conducted for each variable between year 1 and year 2. CI, confidence interval; PP, peak power; MP, mean power: HRR, heart rate recovery. ***, $p < 0.001$.

Discussion

The purpose of this study was to determine the changes in and the tracking of physical activity, sedentary behaviour, and fitness measures in young children over a 12-month period. In our results, we observed increases in VPA, and consequently MVPA, whereas LPA decreased and MPA remained stable. Time to exhaustion on the treadmill increased by 25%, whereas HRR remained unchanged. In addition, PP and MP both increased by about 20%–30% from year 1 to year 2. At both year 1 and year 2, the boys consistently displayed greater physical activity participation, decreased sedentary time, and better performance on fitness tests. As hypothesized, the fitness measures exhibited stronger 12-month tracking than did the physical activity variables. Studying physical activity and fitness over time can be more meaningful than a single "snapshot", especially in the early years, and this prompted us to analyze these variables over time. This work lays the foundation to help explain how these measures change and develop with increasing age and can help us begin to establish whether healthy behaviours, such as physical activity, are truly rooted in the early years.

A nationally representative sample of >400 Canadian preschoolers displayed 342–353 min/day of TPA and 66–68 min/day of MVPA (Colley et al. 2013), whereas our sample engaged in 256–257 min/day of TPA and 96–100 min/day of MVPA. Changes in physical activity were variable between year 1 and year 2 (Table 4). A longitudinal study that assessed physical activity in 3-year-olds observed that they spent 4% of WT in MVPA, and that this had decreased to 2% of WT 2 years later (Reilly et al. 2004). In contrast, Kelly and colleagues (2007) reported that 3- to 4-year-olds spent 2% of WT in MVPA, that this had increased to 4% of WT 24 months later, and that sedentary time had decreased from 80% to 75% of WT. In our study, participants engaged in MVPA for 13% of WT at year 1 and 14% at year 2 (Table 2), with a small increase (0.6% of WT) in sedentary time. The differences between our results and those reported in the literature may be attributed to our shorter accelerometer epoch length (3 s vs. 60 s). In preschoolers, a shorter accelerometer epoch has been shown to capture more MVPA and less LPA and TPA (Colley et al. 2014), compared with a longer epoch. The boys in our study engaged in more physical activity than did the girls, a finding consistent with previous work, which suggests that young boys engage in more TPA (Jackson et al. 2003) and MVPA (Cardon and De Bourdeaudhuij 2008; Grontved et al. 2009) than do girls.

Table 4. Tracking statistics for physical activity and fitness from year 1 (Y1) to year 2 (Y2).

	Change (Y2 – Y1)	Spearman	Strength	κ	Strength
Physical activity					
Sedentary (min/d)	−0.57±45.8	0.61***	Strong	0.32***	Fair
TPA (min/d)	0.9±37.0	0.49***	Moderate	0.26***	Fair
LPA (min/d)	−3.2±21.1*	0.45***	Moderate	0.29***	Fair
MPA (min/d)	0.5±10.3	0.53***	Moderate	0.30***	Fair
VPA (min/d)	3.7±12.4***	0.53***	Moderate	0.31***	Fair
MVPA (min/d)	4.2+20.8***	0.47***	Moderate	0.27***	Fair
Sedentary time (%WT)	0.2±4.5	0.60***	Strong	0.33***	Fair
TPA (%WT)	0.1±4.5	0.59***	Moderate	0.34***	Fair
LPA (%WT)	0.4±2.6*	0.59***	Moderate	0.26***	Fair
MPA (%WT)	0.1±0.4	0.59***	Moderate	0.30***	Fair
VPA (%WT)	0.5±1.7***	0.57***	Moderate	0.38***	Fair
MVPA (%WT)	0.6±2.7	0.59***	Moderate	0.28***	Fair
Fitness					
PP (W)	31.5±17.6***	0.89***	Strong	0.61***	Substantial
PP/kg (W/kg)	1.0±1.0***	0.75***	Strong	0.42***	Moderate
MP (W)	28.2±16.4***	0.86***	Strong	0.56***	Moderate
MP/kg (W/kg)	0.9±0.9***	0.70***	Strong	0.35***	Fair
Treadmill time (min)	2.4±1.4***	0.82***	Strong	0.56***	Moderate
HRR (beats/min)	0.8±14.0	0.52***	Moderate	0.23***	Fair

Note: Physical activity is presented as minutes per day (min/d) and as percentages of wear time (%WT). Short-term muscle power is presented as absolute (W) and relative (W/kg) intensities. The *p* values represent the results of paired *t* tests conducted for each variable between year 1 and year 2. TPA, total physical activity; LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate-to-vigorous physical activity; %WT, percentage of wear time; PP, peak power; MP, mean power; HRR, heart rate recovery. *, $p < 0.5$; ***, $p < 0.001$.

Our physical activity tracking analyses revealed moderate Spearman correlations and fair κ statistics for all intensities. The available physical activity tracking literature for young children is limited. In a sample of one hundred 3- to 4-year-olds, TPA displayed a Spearman tracking coefficient of 0.4 over 1 year (Jackson et al. 2003), whereas a different sample, of forty-two 3- to 4-year-olds, displayed a 24-month Spearman tracking coefficient of 0.37 but a κ statistic of 0.01 (Kelly et al. 2007). In the same sample of young children, tracking of sedentary time displayed a Spearman of 0.35 and a κ statistic of 0.21. The lower tracking in this study may be attributed to the longer follow-up length of 24 months, compared with 12 months in our study. A previous study from our research group, with a small sample of 3- to 5-year-olds, suggested that MVPA and VPA displayed poor tracking on the basis of both Spearman coefficients and κ statistics (Gabel et al. 2011). In our sample, we observed some of the greatest increases in physical activity participation in the participants who engaged in the lowest volumes of physical activity at year 1 and vice versa for those who engaged in the highest volumes of physical activity at year 1. In agreement with the literature, these tracking results imply that engagement in physical activity is variable in the early years and may not predict future physical activity participation.

Performance on fitness tests improved with increasing age in the early years, and this was evident in both our results and the related literature. Changes in fitness with increasing age in childhood and adolescence may be attributed to growth, neuromuscular factors, hormonal factors, and coordination (Van Praagh and Doré 2002). A recent study that assessed muscular strength, power, and velocity determined that age-related differences in strength in the early years were, for the most part, caused by changes in body weight (Fry et al. 2015). The early years are also a period of rapid locomotor, stability, and balance development (Parizkova 1996), and this likely contributes to better performance on fitness tests as children grow in age and size (Cumming et al. 1978). The 30% increase in STMP we observed in our sample was similar to the findings of a small cross-sectional study that observed that 5-year-olds performed better than 3- and 4-year-olds on the same 10-s WAnT protocol (Nguyen et al. 2011). Performance on field-based STMP tests, such as the 20- or 25-m dash, also improves with increasing age in the early years (Gabel et al. 2011; Parizkova 1996), and this trend has been seen in performance on aerobic fitness tests as well.

In our sample, treadmill time increased by 25%, whereas HRR was unchanged from year 1 to year 2. Theoretically, the preschoolers could have had improved performance on the treadmill test from year 1 to year 2 because of changes in growth, coordination, and/or motivation, and not necessarily because of changes in fitness. HRR decreases with increasing age and growth (Cumming et al. 1978; Singh et al. 2008), but it is not known how much change is expected over 12 months in the early years. In our sample, HRR remained unchanged from year 1 to year 2. It has been reported that children achieved similar maximal oxygen uptake values but poorer performance on aerobic fitness tests compared with adults, suggesting that factors other than fitness influenced their performance (Simons-Morton et al. 1988). Using the Bruce Protocol, Cumming and colleagues (1978) observed times to exhaustion of 10.0 min in 4- to 5-year-olds and 11.5 min in 6- to 7-year-olds. This compares to 9.4 min at year 1 (3- to 5-year-olds) and 11.8 min at year 2 (4- to 6-year-olds) in our sample. HRR in our sample was stable from year 1 to year 2 at 65 beats/min and was comparable to a sample of 4- to 6-year-olds who achieved HRR values of 59–69 beats/min after the Bruce Protocol (Mimura and Maeda 1989). Aerobic fitness tests have been performed more commonly than STMP assessments in preschoolers, but there is still limited tracking, and few longitudinal data are available.

Fitness measures have demonstrated better tracking than physical activity measures in our sample and in the literature. Spearman tracking was strong for PP (W/kg) and MP (W/kg), whereas PP exhibited moderate tracking and MP exhibited fair tracking on the basis of κ statistics. Using the same WAnT protocol but with a smaller sample size, strong Spearman tracking was observed, whereas κ statistics showed moderate PP/kg and almost perfect MP/kg tracking (Gabel et al. 2011). Differences in κ tracking could be a result of differences in sample sizes between studies. With more scores in a larger sample, there are more likely to be many "tied" scores and the distribution of scores will be narrower. Tracking of aerobic fitness in preschoolers with the Bruce Protocol has not been reported in the literature; however, other aerobic fitness measures have been discussed. In a sample of kindergarten students, Spearman tracking correlations were moderate for performance on a 1-mile walk–run test, a measure of aerobic fitness (McMillan and Erdmann 2010). In our study, treadmill time exhibited strong, and HRR displayed moderate, tracking, on the basis of Spearman results. It may not be surprising that fitness tracked better than did physical activity because the latter represents the behaviour of performing movement, whereas fitness refers to the characteristics that influence one's ability to carry out physical activity (Armstrong 2006).

Although this study generated novel information about physical activity and fitness in the early years, it is not without limitations. Most tracking studies investigate longer time periods, but 12 months is a significant portion of a young child's life. Therefore, it is expected that the rapid growth and development of these participants would induce changes in physical activity and fitness over this time period. Additional time points would add to the potential impact of these results. The success of the testing sessions was often influenced by the cooperation, motivation, and attention of the young participants. The assessors worked hard to develop rapport and were encouraging to all the children during the testing sessions. Aerobic fitness was assessed indirectly by monitoring the children's HRs during the Bruce Protocol. This test has been used to assess aerobic fitness in preschoolers since the 1970s; however, the reliability of this treadmill test and the strong relationship between time to exhaustion and oxygen uptake have been determined only in children as young as 7 years old (Cumming et al. 1978). The STMP test on the cycle ergometer was, anecdotally, very popular among the young participants; however, some young children did not have the full ability to pedal the bicycle for the 10 s of the WAnT. The incorporation of an additional measure of STMP, such as a running dash or a long jump, or measures of strength, could be valuable. Physical activity data may have been affected by season because assessments were done only once per year. Of the year 2 visits, 97% occurred within 12 ± 1 months of the year 1 visits, so it can be assumed that assessments took place in the same season. However, differences in weather between year 1 and year 2 may have contributed to changes in physical activity. The accelerometers cannot be worn while swimming, so any activity in a pool would have been missed. In addition, our 1 week of PA monitoring may not have been reflective of habitual physical activity in all our participants. Last, we used accelerometer cut-points that were validated in 3- to-5-year-olds (Pate et al. 2006). At year 2, a third of the sample were 6 years old; however, no set of physical activity cut-points that encompasses our entire age range currently exists. The handling of longitudinal data that spans multiple cut-point ages is a topic that will require further investigation.

In summary, young children improved performance on fitness tests over a 1-year period, whereas changes in physical activity were more variable. The improvements in fitness may be attributed largely to changes in growth; therefore, the investigation of tracking was important. Fitness measures displayed stronger tracking than did physical activity measures. Further investigation to determine why physical activity participation is so dynamic, as well as to determine the health consequences of such activity in young children, is warranted. These results suggest that healthy behaviours, such as physical activity participation, may not be set in the early years and that health promotion initiatives and programming targeted at the early years should encourage participation in all children, regardless of current activity level.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Acknowledgements

The HOPP study is funded by the Canadian Institutes of Health Research (CIHR) (awardno. MOP 102560). B.W.T. is supported by a CIHR New Investigator Award. J.C. is supported by an endowed professorship through the Department of Family Medicine, McMaster University. H.A.T.C. and S.K.-D. were supported by Ontario Graduate Scholarships.

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