Analysis of sex and age differences in performance of young Canadian freestyle swimmers

TIANYUE RUBY SUN

White Oaks Secondary School, Oakville, Canada

ABSTRACT

This study is intended to determine sex and age differences in young Canadian freestyle swimmers aged from ≤10 to 18, for all 6 distances from 50m to 1500m in both short and long course indoor pools. The data set used in the studies is publicly available and categorized into sex/age/course/distance groups during seasons from 2008 to 2019. The sex differences in swimming speed were determined using independent Z-tests (two-sided, unequal SD). The age differences in swimming speed over all ages were analysed using classic one-way ANOVA with subsequent pairwise Tukey-HSD post-hoc tests and Welch's ANOVA followed by pairwise Games-Howell post-hoc tests. They were then determined using paired two-sample t-tests (two-sided). Young male swimmers outperformed young female swimmers in most groups. Groups with similar performances or no significant differences were in younger age groups (10-year and 11-year). Sex differences increased as age increased, ranging from −0.96% to 13.54%. Sex differences in shorter distances and short course were smaller than in longer distances and long course for ≤12 years and became greater than in longer distances at ≥13 years. Age speed differences decreased as age increased until 17–18-years old, ranging from 12.79% to −0.37%. The performance of female swimmers became stable earlier than that of male swimmers. The age-to-age speed differences of male swimmers were greater than those of female swimmers. These gaps increased from 10–11-year to 13–14-year groups and decreased after that. Age differences in shorter distances and short course were greater than in longer distances and long course. Further studies are required to confirm and extend this research to swimmers at other age groups, in other strokes, and from other countries.
Keywords: Swimming speed; Sex difference; Age difference.

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Corresponding author. *White Oaks Secondary School, Oakville, ON L6H 1Z5, Canada.*
E-mail: suntianyuer@gmail.com
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INTRODUCTION

Age and sex are well-known factors influencing competitive swimming performance. Sex and age differences in swimming performance have been investigated in a few recent studies. Tanaka H. & Seals D.R. (1997) analysed age and gender interactions of top freestyle performance times from the US Masters Swimming Championships. Trewin C.B., (2004) studied sex differences in international swimming performance by modelling world-ranking times and best times from the 2000 Olympic Games. Medic N. et al. (2009) examined gender and age differences in relative age effects in US Masters Swimming National Championships from 1998 to 2006. Wolfrum, M. et al. (2013) compared performance and age of peak performance in breaststroke versus freestyle for female and male swimmers at national and international levels in 50m, 100m, and 200m race distances. Koch-Ziegenbein P. et al. (2013) examined the sex difference in breaststroke swimming speeds at national and international levels between short course and long course in distances including 50m, 100m, and 200m. Rüst, C.A. et al. (2014) reported the age and the sex difference in peak freestyle swimming speed for all distances between 50m and 1500m for elite female and male swimmers competing at the national level. Zingg M.A. et al. (2014) investigated the changes in swimming speeds and sex differences for elite male and female swimmers competing in 5km, 10km and 25km open-water FINA World Cup races held between 2000 and 2012. Wild S. et al. (2014) investigated swimming speeds and sex differences of all strokes and distances at the Olympic Games and FINA World Championships between 1992 and 2013.

Most existing studies were conducted with adult elite swimmers at national and international levels as the subjects. Data used in existing research were a relatively small number of samples selected from a big data set. In Tanaka H. (1997), top 10 winning times in 5-yr (1991–1995) US Masters Swimming Championships were used in the analysis. In Trewin C.B., (2004), 407 top 50 world-ranked swimmers were used in the study. In Wolfrum M. et al. (2013), swimming performance of top three athletes in separated age/sex/distance groups at national and international levels were examined. In Koch-Ziegenbein P. et al. (2013), top 10 men and women were selected for elite female and male swimmers competing at national and international levels in years from 2000 to 2011 to determine the change in swimming speed across years. In Rüst, C.A. et al. (2014), the annual three fastest race times of each distance from 2006 to 2010 were used in the analysis. In Wild S. et al. (2014), the finalists competing at the Olympic Games (i.e., 624 female and 672 male athletes) and FINA World Championships (i.e., 990 women and 1008 men) between 1992 and 2013 were used in the analysis.

To the best of our knowledge, little studies on sex and age differences in swimming performance have been carried out with a focus on young swimmers in each age group before the age of 18, with the consideration of not only top swimmers at elite and master levels but also the remaining large number of ordinary swimmers. For coaches and young swimmers, the knowledge of sex and age-to-age differences in swimming speed of all levels of swimmers may help them understand the progress, phase, and position of a swimmer's performance at his or her early age and make plans for the training and career of an athlete accordingly. Since young swimmers have quite different characteristics in swimming performance when comparing to adult swimmers, it might be argued that research results obtained from adult swimmers may not be easily extended to the case of young swimmers. Similarly, results on performance and progress obtained from selected top swimmers may not be applicable to the large number of swimmers at the ordinary level. Using a small number of selected samples may also bring bias to the study when generalizing the results to be applicable to the population. A larger number of samples representing swimmers at all levels must be adopted in research to gain insights into the performance differences using statistical approaches.

In addition to sex, age, and swimming distance, another factor affecting the performance of a swimmer is the different types of indoor swimming pools which can be either long course metres (LCM, i.e., a pool 50 metres in length) and short courses metres (SCM, i.e., a pool 25 metres in length). While most existing research on swimming performance only considered LCM, there are recent studies that have investigated differences between LCM and SCM, including a study which focused on breaststroke swimming performance of course distances 50m, 100m, and 200m (Koch-Ziegenbein P. et al. 2013) and one that examined medley swimming performance of course distances 200m and 400m (Wolfrum, M. et al. 2014), both in national and international levels with selected top 10 athletes. Research across short (50 and 100 metres), intermediate (200 and 400 metres), and long (800 and 1500 metres) distances in both LCM and SCM pools is needed to gain an integral understand on sex and age differences of freestyle swimming performance.

The aims of the present study were to examine the sex and age differences in swimming speed for young freestyle swimmers aged ≤18 years in all events with distances including 50m, 100m, 200m, 400m, 800m, and 1500m in both LCM and SCM courses. The data set used in this study was publicly available and included Canadian swimmers at age from ≤10 years to 18 years who have raced during 2008 and 2019 seasons in at least one of the 12 freestyle events (2 courses, 6 distances). Comparisons were conducted between sex/age/course/distance groups.

METHODS

Data sampling and data pre-processing

The data set used in this study was publicly available at the website "*Swimming Canada*" (URL: https://www.swimming.ca/). Data of young freestyle swimmers in 12 consecutive seasons between 2008 and 2019 were collected. All athletes were separated by sex categories in 9 age groups from ≤10 to 18 years. For each sex/age group, the annual best times in each of the 6 distances (i.e., 50m, 100m, 200m, 400m, 800m, and 1500m freestyle) in both LCM and SCM pools were obtained. Data of 1,077,410 best times from 65,065 female swimmers and 753,192 best times from 44,341 male swimmers were available. The total number of observations was 1,830,602, which were categorized into 2,592 groups (i.e., 12 seasons, 2 genders, 9 ages, 2 courses, and 6 distances). Since the ranking list recorded only the best time achieved by a swimmer in a season, no swimmer was included repeatedly in a group.

A one-way analysis of variance (ANOVA) across seasons showed no significant differences in best times across these 12 seasons. Therefore, the 2,592 groups were collapsed into 216 groups by removing the season factor. Outliers in each group were identified (Z-score = 3) and eliminated to avoid the effect of distant observations. The filtered data set had a total of 1,811,459 observations with 1,066,317 best times from 63,877 female swimmers and 745,142 best times from 43,571 male swimmers. Swimming times (in seconds, s) as a measure of swimming performance of each group were depicted with boxplots in Figure 1. For analysing performance differences in sex and age, race time was converted to swimming speed (metres per second, m/s) by calculating [race distance (m)] / [race time (s)]. Figure 2 depicts the swimming speed of each group with error bar (mean ± standard deviation (SD)).

Statistical analysis

Prior to statistical analyses, each group of data was tested for normality and for homogeneity of variances. Normality was tested both graphically using a histogram and formally using Shapiro-Wilk Test, D'Agostino-Pearson's Test, and Anderson-Darling Test. Homogeneity of variances was tested using Levene's test and Bartlett's test.

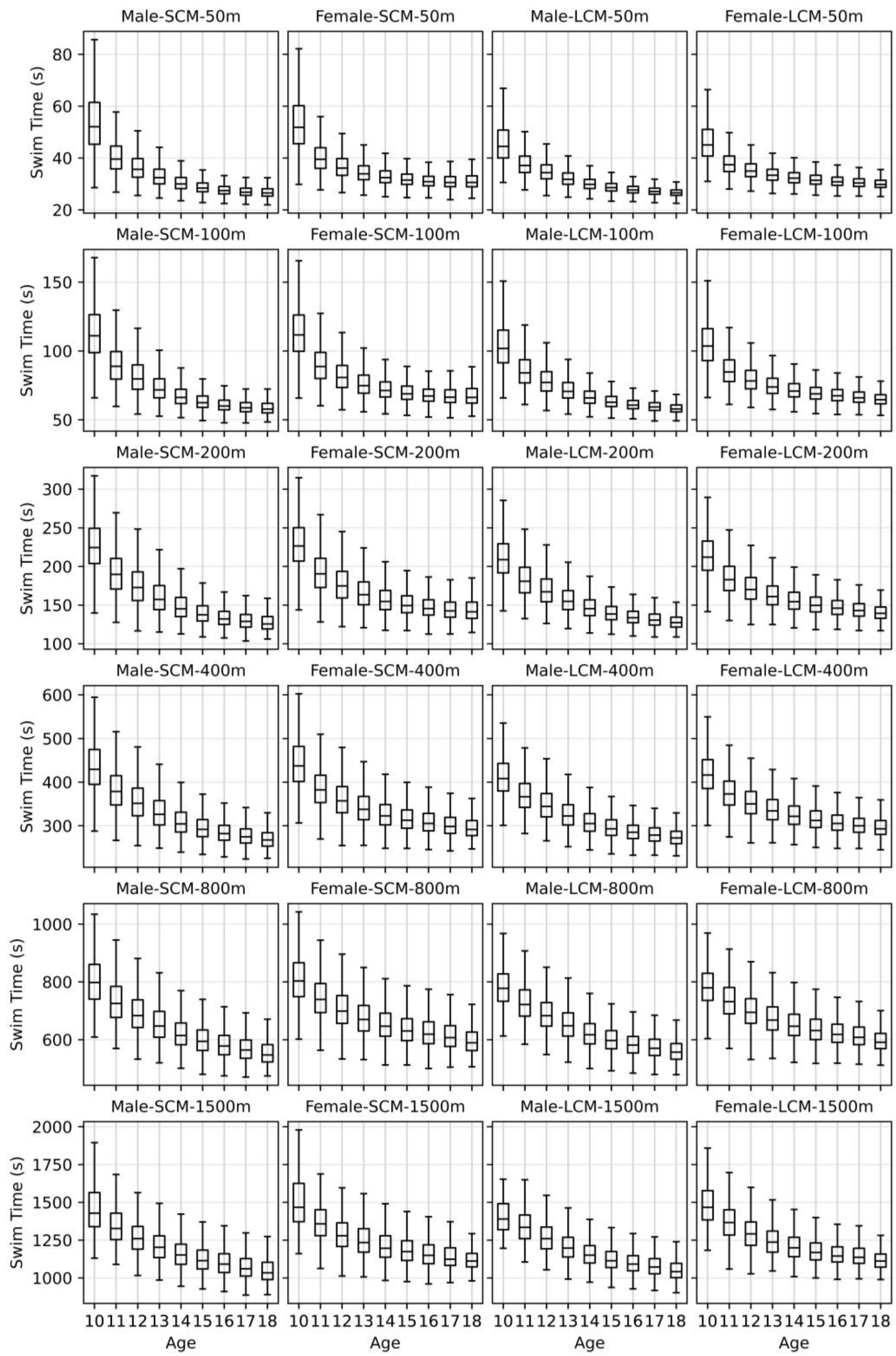

Figure 1. Performance data of race time grouped by sex/course/distance/age.

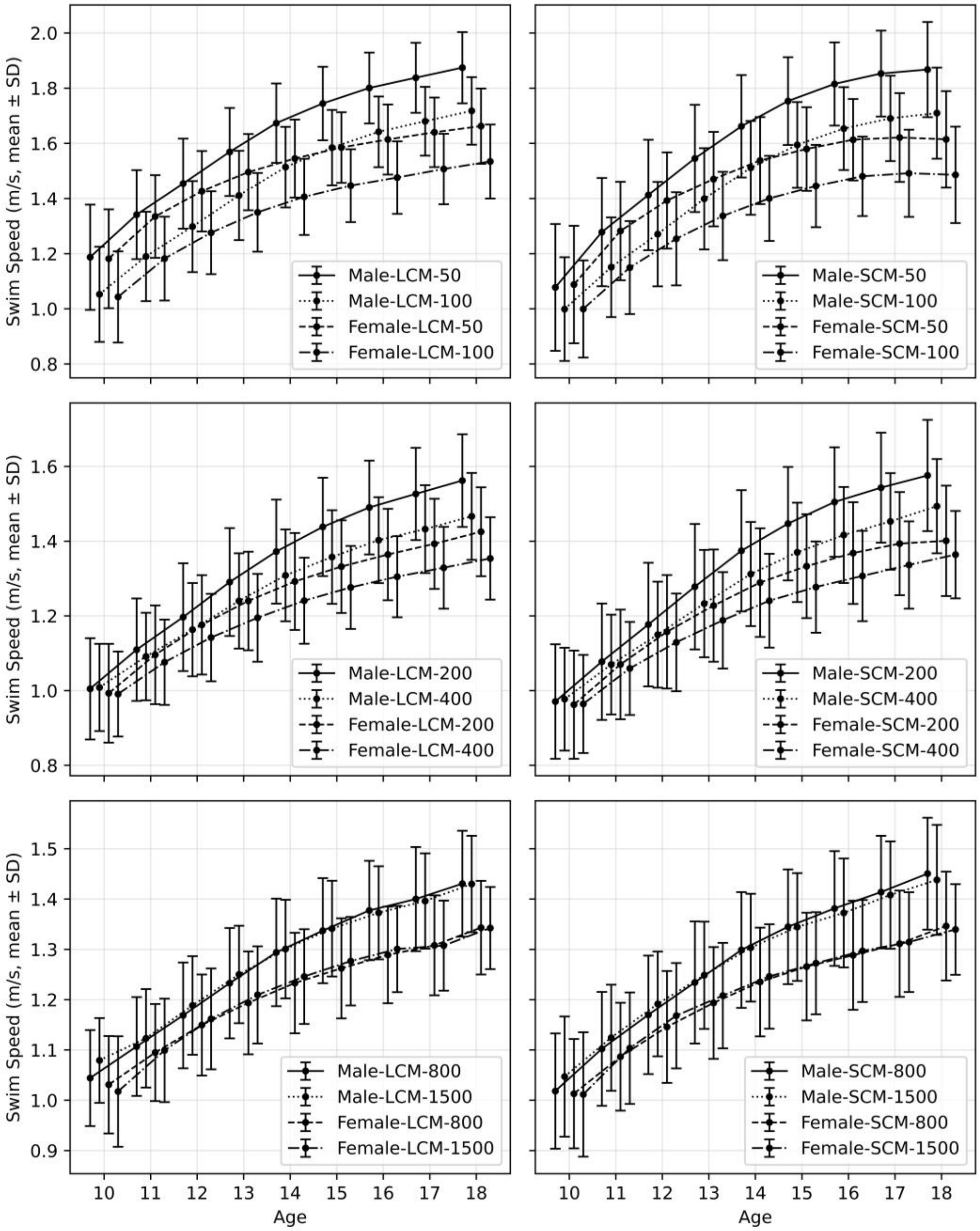

Figure 2. Swimming speed of sex/course/distance/age groups.

The sex differences in swimming speed between age/course/distance groups were determined using independent Z-tests (two-sided, unequal SD). The sex speed difference (m/s) is defined as [swimming speed in men (m/s)] – [swimming speed in women (m/s)]. The sex difference in percent (%) is defined as ([swimming speed in men (m/s)] – [swimming speed in women (m/s)]) / [swimming speed in men (m/s)] ×100%. Significance was accepted at $p < .05$.

The age differences over sex/course/distance groups were analysed in two steps. In the first step, the differences in swimming speed over all ages within each sex/course/distance group were analysed using a classic one-way ANOVA with subsequent pairwise Tukey-HSD post-hoc tests and Welch's ANOVA followed by pairwise Games-Howell post-hoc tests. In the second step, swimmers having raced in two contiguous ages from ≤10 to 18 were selected, and numerical results on age-to-age differences (i.e., ages between 11 and 10, 12 and 11, 13 and 12, 14 and 13, 15 and 14, 16 and 15, 17 and 16, and 18 and 17) were determined using paired two-sample t-tests (two-sided). As pairwise comparisons in the post-hoc tests of the first step revealed that paired age groups were not significantly different ($p > .05$) were all from 16, 17, and 18 years, age-to-age differences between 16 and 18 years were also analysed. Age speed difference (m/s) is defined as [swimming speed in older age (m/s)] – [swimming speed in younger age (m/s)]. Age difference in percent (%) is defined as ([swimming speed in older age (m/s)] – [swimming speed in younger age (m/s)]) / [swimming speed in younger age (m/s)] ×100%. Significance level for tests was at $p < .05$.

Statistical analyses were performed using the Python programming language (Version 3.8.2) in Jupyter Notebook development environment using Anaconda with other open-source modules, including math, matplotlib, numpy, pandas, pingouin, scipy, and statsmodels.

RESULTS

Sex differences

Sex differences in swimming speed between course/distance/age groups are shown in Figure 3. Men outperformed women in most groups with an increasing speed differences over ages ($p < .05$). Groups with similar performance or no significant differences were all in younger age groups in 10-year and 11-year, including SCM-100m-10y ($p = .84$), SCM-800m-10y ($p = .27$), LCM-50m-10y ($p = .05$), LCM-800m-10y ($p = .03$), SCM-50m-11y ($p = .03$), and SCM-100m-11y ($p = .50$). Three groups were of negative mean difference (meaning women outperformed men), including SCM-50m-10y (−0.01 ± 0.00), SCM-100m-10y (−0.00 ± 0.00), and SCM-50m-11y (−0.00 ± 0.00). The average sex difference in swimming speed increased from 0.01 m/s at age 10 to 0.15 m/s at age 18. For example, for group SCM-200m, the speed differences between sex groups increased from 0.01 ± 0.0 m/s (mean ± 95% CI) in age group ≤10 to 0.17 ± 0.001 m/s in age group 18. Also, as visible from the lengths of the error bars in Figure 3, variations in sex differences increased as distances increased. The variations in age groups became smaller from 10-year to 14-year and larger from 14-year to 18-year.

Figure 4 and Table 1 show the sex differences in percent (%) between course/distance/age groups. Sex differences increased as age increased in most groups, ranging from −0.96% to 13.54%. For example, in group LCM-100m, the speed differences changed from 0.9 ± 0.24% at 10 years to 10.68 ± 0.23% at 18 years. Decreased sex differences happened from 10-year to 11-year age groups, in SCM-200m (0.86 ± 0.18% to 0.69 ± 0.16%), SCM-400m (1.31 ± 0.23% to 0.98 ± 0.18%), SCM-1500m (3.39 ± 1.12% to 1.86 ± 0.51%), LCM-100m (0.9 ± 0.24% to 0.66 ± 0.19%), LCM-400m (1.74 ± 0.29% to 1.41 ± 0.21%), LCM-800m (1.27 ± 0.59% to 1.09 ± 0.29%), LCM-1500m (5.72 ± 1.32% to 2.14 ± 0.61%), and from 17-year to 18-year groups in SCM-800m (7.25 ± 0.24% to 7.18 ± 0.37%), LCM-800m (6.57 ± 0.28% to 6.11 ± 0.38%), and LCM-1500m (6.35 ± 0.34% to 6.12 ± 0.47%). For age groups in ≤12-year, sex differences in shorter distances were smaller than in longer distances. For example, sex differences in group LCM-11y changed from 0.5 ± 0.16% in 50m and 0.66 ± 0.19% in 100m to 1.09 ± 0.29% in 800m and 2.14 ± 0.61% in 1500m. Afterwards, 12-year sex differences in shorter distances became greater than in longer distances. For example, sex differences in group SCM-16y changed from 11.14 ± 0.13% in 50m and 10.46 ± 0.15% in 100m to 10.46 ± 0.15% in 800m and 5.51 ± 0.27% in 1500m. Finally, sex differences in SCM were smaller than in LCM for age groups in ≤12-year, and greater for ≥13-year, as visible directly in Figure 4, where the SCM lines have larger slopes as the LCM lines.

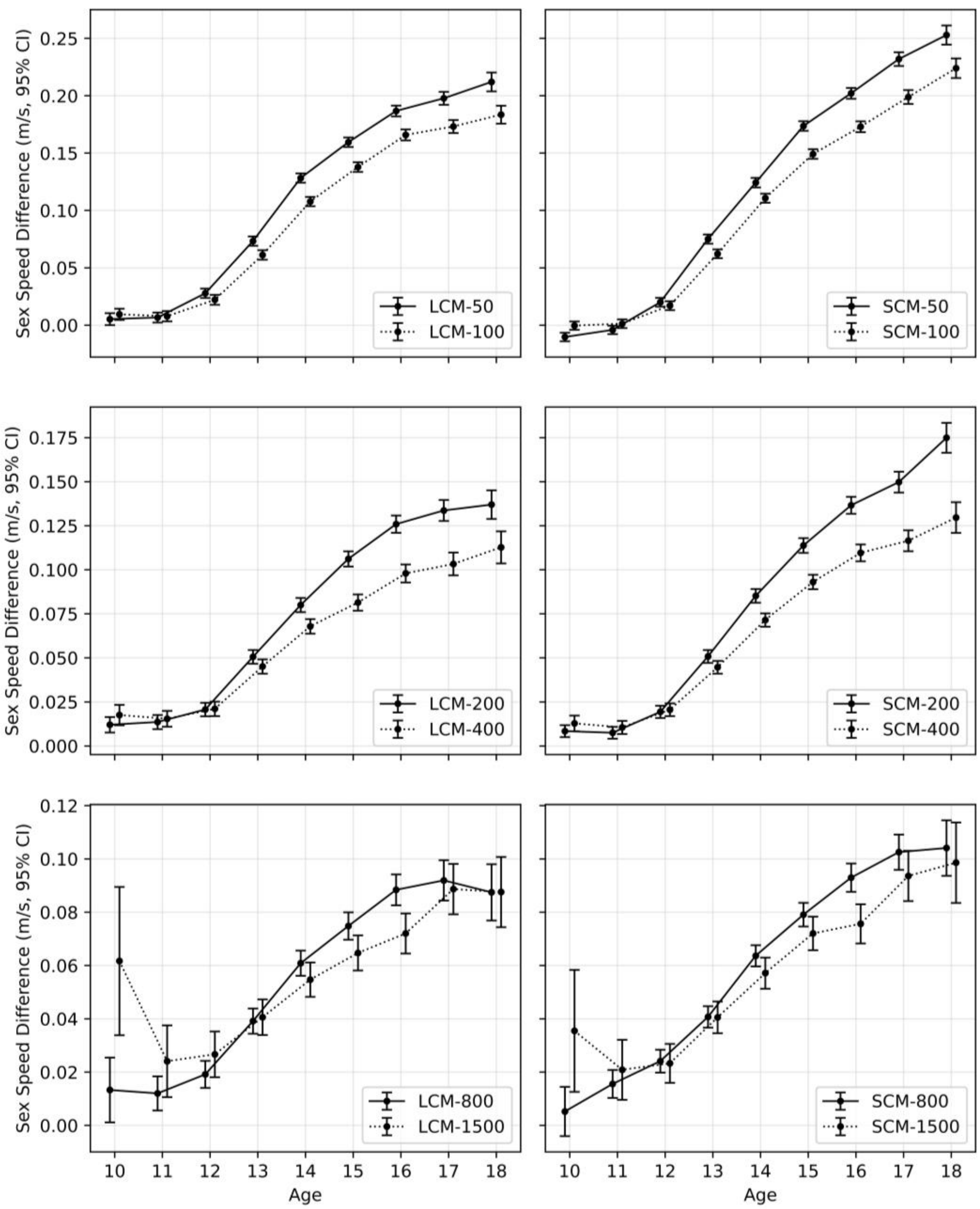

Figure 3. Sex differences in swimming speed (m/s, 95% CI) between course/distance/age groups.

Table 1. Sex differences in percentage (%) between course/distance/age groups.

Course	Distance	10-year	11-year	12-year	13-year	14-year	15-year	16-year	17-year	18-year
SCM	50	-0.96±0.18	-0.32±0.15	1.42±0.14	4.86±0.13	7.48±0.13	9.9±0.12	11.14±0.13	12.52±0.16	13.54±0.23
	100	-0.04±0.18	0.11±0.17	1.34±0.16	4.45±0.14	7.33±0.13	9.36±0.13	10.46±0.15	11.76±0.18	13.1±0.25
	200	0.86±0.18	0.69±0.16	1.64±0.15	3.98±0.15	6.2±0.14	7.86±0.15	9.08±0.16	9.7±0.2	11.1±0.27
	400	1.31±0.23	0.98±0.18	1.79±0.16	3.62±0.15	5.45±0.15	6.79±0.15	7.74±0.17	8.02±0.21	8.68±0.3
	800	0.51±0.46	1.41±0.24	2.06±0.19	3.3±0.17	4.9±0.16	5.88±0.17	6.73±0.2	7.25±0.24	7.18±0.37
	1500	3.39±1.12	1.86±0.51	1.95±0.31	3.25±0.24	4.38±0.23	5.36±0.24	5.51±0.27	6.65±0.34	6.85±0.54
LCM	50	0.44±0.22	0.5±0.16	1.91±0.14	4.67±0.13	7.67±0.12	9.14±0.12	10.37±0.13	10.76±0.16	11.31±0.22
	100	0.9±0.24	0.66±0.19	1.71±0.17	4.34±0.15	7.12±0.14	8.7±0.14	10.1±0.15	10.31±0.17	10.68±0.23
	200	1.2±0.22	1.22±0.18	1.73±0.16	3.92±0.15	5.83±0.15	7.38±0.15	8.45±0.17	8.75±0.2	8.77±0.27
	400	1.74±0.29	1.41±0.21	1.81±0.18	3.64±0.17	5.19±0.16	6.0±0.17	6.98±0.19	7.21±0.23	7.69±0.32
	800	1.27±0.59	1.09±0.29	1.64±0.22	3.18±0.2	4.7±0.19	5.6±0.2	6.42±0.21	6.57±0.28	6.11±0.38
	1500	5.72±1.32	2.14±0.61	2.24±0.37	3.25±0.27	4.21±0.25	4.82±0.25	5.25±0.28	6.35±0.34	6.12±0.47

Table 2. Age-to-age differences in percent (%) over sex/course/distance groups.

Sex	Course	Distance	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	16-18
Men	SCM	50	11.65±8.34	10.65±7.13	8.82±5.83	6.74±4.65	4.18±3.81	2.52±3.04	1.41±2.78	0.63±3.06	2.15±3.57
		100	12.45±8.2	11.27±7.45	9.48±6.15	7.19±4.91	4.44±3.99	2.59±3.29	1.42±3.06	0.55±3.18	2.16±3.96
		200	12.06±7.71	10.91±7.04	9.04±6.02	6.96±5.01	4.3±4.26	2.54±3.6	1.13±3.43	0.5±3.31	2.04±4.27
		400	11.53±7.51	10.0±6.76	8.32±5.94	6.24±5.11	3.88±4.49	2.1±3.86	0.9±3.71	0.22±3.72	1.58±4.48
		800	11.15±6.51	8.95±5.91	7.37±5.2	5.79±4.62	3.52±4.13	1.85±3.54	0.81±3.33	0.16±3.07	1.25±4.07
		1500	9.32±5.67	7.97±5.31	6.94±4.49	5.45±4.0	3.47±3.65	1.63±3.32	0.77±3.02	0.48±2.92	1.47±3.84
	LCM	50	11.12±7.65	9.42±6.16	8.12±5.33	6.19±4.28	3.84±3.57	2.36±3.01	1.34±2.75	0.65±2.64	2.35±3.58
		100	12.38±7.86	10.51±6.67	9.03±5.83	6.7±4.58	4.25±3.85	2.46±3.11	1.32±2.89	0.41±2.78	2.13±3.6
		200	11.82±7.32	9.82±6.27	8.37±5.6	6.34±4.71	4.03±4.02	2.23±3.38	1.06±3.09	0.21±3.12	1.66±3.88
		400	10.71±6.7	8.88±5.87	7.63±5.47	5.61±4.83	3.55±4.19	1.94±3.65	0.68±3.36	0.13±3.27	1.37±4.08
		800	9.98±6.02	8.14±5.13	6.85±4.89	5.17±4.3	3.27±3.88	1.79±3.32	0.7±3.16	0.27±3.0	1.33±3.66
		1500	8.73±4.28	7.47±4.81	6.34±4.51	4.63±3.97	3.02±3.57	1.65±2.87	0.77±2.84	0.32±2.49	1.51±3.23
Women	SCM	50	11.97±7.7	8.78±5.99	5.22±4.79	3.18±3.81	1.49±3.36	0.64±3.09	0.08±2.98	-0.16±3.14	0.06±3.7
		100	12.75±7.74	9.64±6.32	5.94±5.08	3.56±4.1	1.7±3.4	0.75±3.24	0.06±3.19	-0.14±3.46	0.02±4.09
		200	12.38±7.41	9.67±6.26	5.92±5.06	3.71±4.17	1.83±3.65	0.85±3.33	0.09±3.22	-0.09±3.39	0.25±4.21
		400	11.81±7.15	8.82±5.9	5.69±5.15	3.49±4.24	1.79±3.65	0.84±3.38	0.13±3.26	-0.27±3.16	0.18±4.19
		800	11.37±6.4	7.97±5.18	5.38±4.59	3.23±3.77	1.69±3.29	0.75±3.07	0.08±2.9	0.05±2.75	0.45±3.52
		1500	11.24±7.19	8.0±4.83	4.95±4.23	3.29±3.7	1.74±3.35	0.81±3.08	0.35±2.7	0.26±2.71	0.97±3.29

	LCM	50	11.42±7.19	7.94±5.25	4.81±4.35	2.88±3.63	1.45±3.12	0.61±2.91	0.15±2.77	-0.36±2.73	0.21±3.15
		100	12.79±7.53	9.2±5.76	5.81±4.88	3.37±3.91	1.73±3.35	0.71±3.04	0.19±2.85	-0.37±2.91	0.25±3.49
		200	12.2±7.12	8.96±5.57	5.59±4.78	3.37±3.88	1.75±3.51	0.82±3.14	0.13±2.92	-0.3±2.88	0.35±3.57
		400	11.05±6.52	8.22±5.42	5.18±4.68	3.23±4.12	1.65±3.67	0.72±3.34	0.2±3.12	-0.3±3.02	0.39±3.65
		800	10.56±6.07	7.18±4.85	4.69±4.27	3.04±3.64	1.45±3.24	0.76±2.92	0.1±2.9	0.01±2.56	0.4±3.22
		1500	10.76±8.73	6.49±4.36	4.32±4.03	2.89±3.52	1.61±2.95	0.69±2.55	-0.02±2.58	0.17±2.25	0.33±2.51

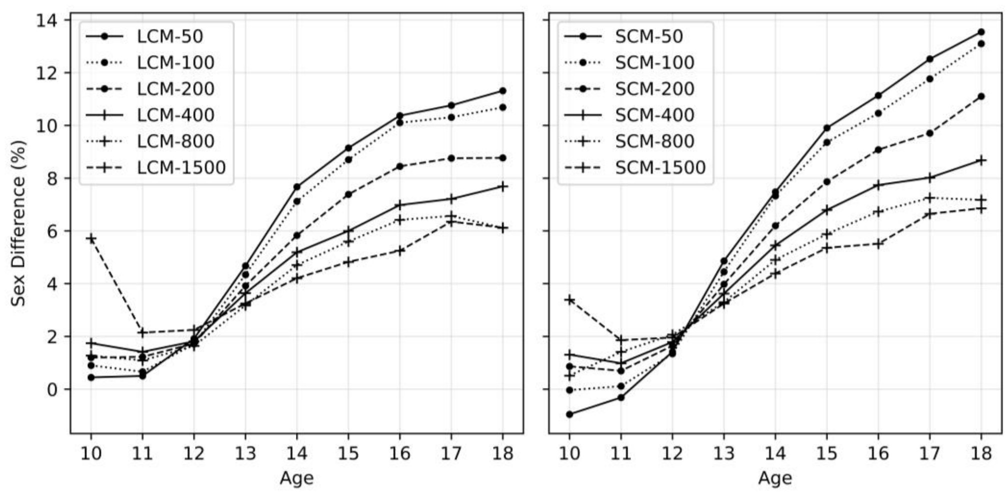

Figure 4. Sex differences in percentage (%) between course/distance/age groups.

Age differences

Age groups reported to have no significant differences (p > .05), as analysed using pairwise Tukey-HSD post-hoc tests and pairwise Games-Howell post hoc tests in female swimmers among age groups 16-year, 17-year, and 18-year, including SCM-50m-16y-18y, SCM-50m-17y-18y, SCM-100m-16y-18y, SCM-100m-17y-18y, SCM-200m-17y-18y, SCM-1500m-16y-17y, LCM-1500m-16y-17y. Detailed comparisons of swimming speed between age groups over course/distance/sex using paired two-sample t-tests (two-sided) are shown in Figure 5. Speed differences (m/s) decreased as age increased, until the 17–18-year-old group when no significant differences were observed in some female groups. The speed differences based on age of men are greater than those of women, meaning male swimmers improve more than female swimmers over time.

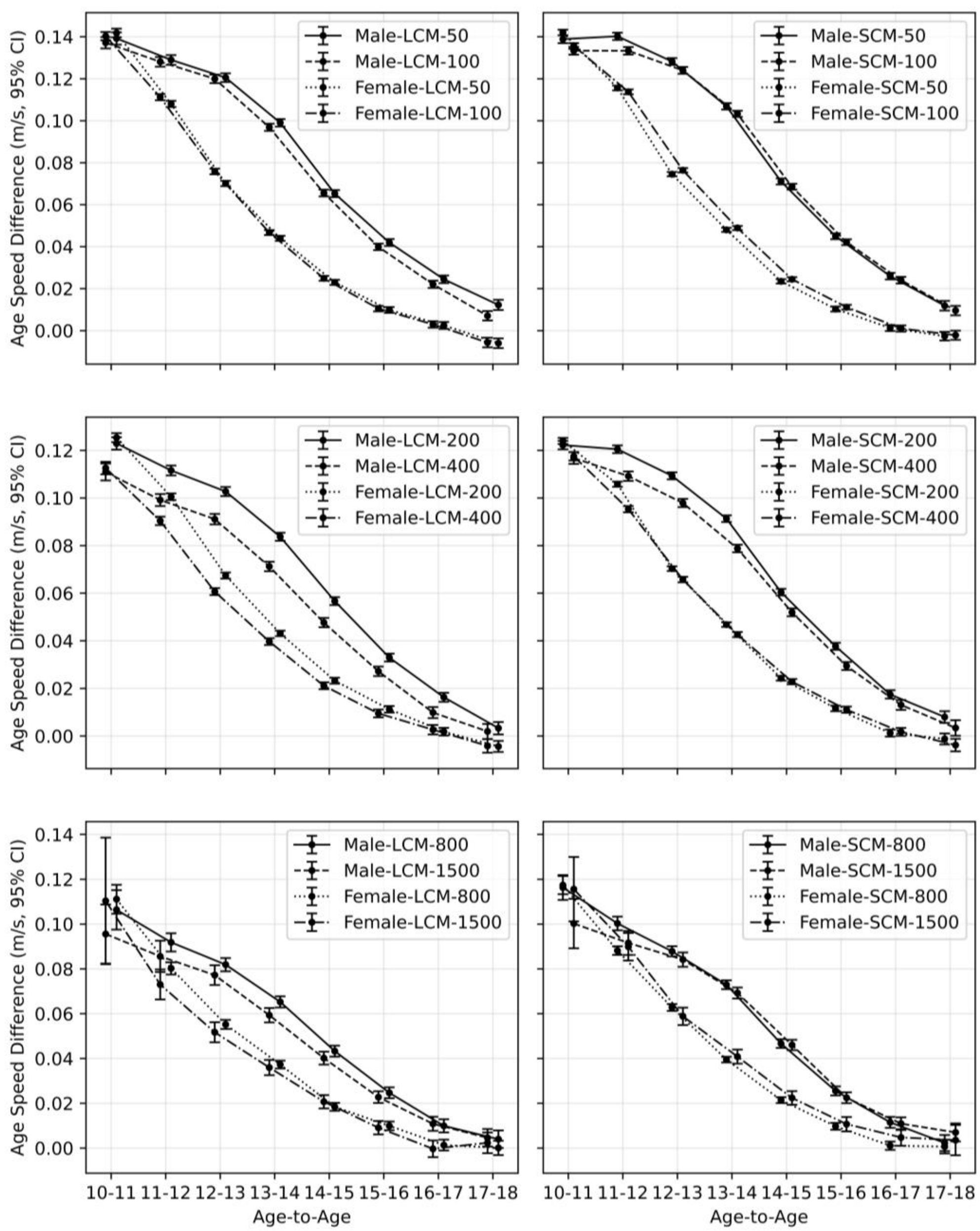

Figure 5. Age-to-age differences in swimming speed (m/s, 95% CI) over sex/course/distance groups.

Figure 6 and Table 2 show the age-to-age differences in percentage (%) between course/distance/sex groups, in a range from −0.37% to 12.79%. The speed difference gaps between sex groups became greater from younger ages since 10–11-year until 13–14-year groups and became smaller after that. For example, for SCM-100m, the difference gaps between sex groups increased from −0.3% between 10–11-year groups to 3.63% between 13–14-year groups and decreased after that to 0.69 between 17–18-year groups. In general, age differences in shorter distances were greater than in longer distances, with 100m having the greatest differences, followed by 200m, 50m, 400m, 800m, and 1500m. In terms of courses, differences in SCM groups were slightly greater than in LCM groups. Finally, the results for age groups 16–17-year, 17–18-year, and 16–18-year also confirmed the observations obtained from the two post-hoc tests. In particular, only two male groups, SCM-800m-17y-to-18y (p = .21) and LCM-400m-17y-to-18y (p = .22), reported no significant differences in swimming speed. In comparison, a number of 15 out of 36 female swimmer groups reported no significance differences between age groups, including SCM-50m-16y-to-17y (p = .09), SCM-50m-16y-to-18y (p = .44), SCM-100m-16y-to-17y (p = .18), SCM-100m-16y-18y (p = .82), SCM-200m-16y-to-17y (p = .10), SCM-200m-17y-to-18y (p = .30), SCM-400m-16y-to-18y (p = .17), SCM-800m-16y-to-17y (p = .26), SCM-800m-17y-to-18y (p = .67), SCM-1500m-17y-to-18y (p = .30), LCM-800m-16y-to-17y (p = .28), LCM-800m-17y-to-18y (p = .95), LCM-1500m-16y-to-17y (p = .87), LCM-1500m-16y-to-18y (p = .12), and LCM-1500m-17y-to-18y (p = .32).

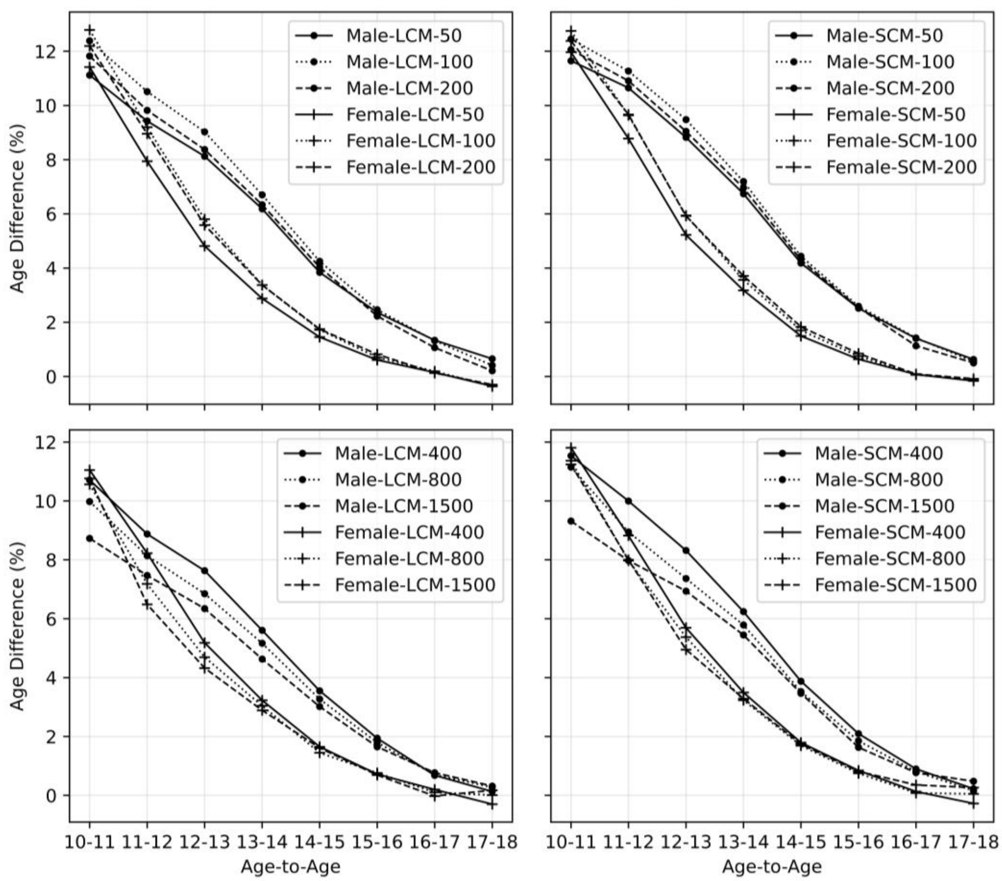

Figure 6. Age-to-age differences in percent (%) over sex/course/distance groups.

DISCUSSION

This study is intended to determine the sex and age differences in young freestyle swimmers at ages ≤10 to 18 for the 6 distances from 50m to 1500m in both SCM and LCM pools. The data set used in the studies includes publicly available youth Canadian swimmers categorized in sex/age/course/distance groups from season 2008 to 2019.

Young male swimmers outperform young female swimmers in most groups for ages from ≤10 to 18. Groups with similar performance or no significant differences are all in younger age groups in 10-year and 11-year. Sex differences increased as age increased, in range −0.96% to 13.54%. The results agree with other studies in sports of both swimming (Knechtle, B. 2020) and other disciplines such as running (Cheuvront S.N. et al. 2005, Helgerud J. et al. 1990, Stark, D. et al. 2020) and cycling (Baumgartner S. et al. 2020, Lepers R. et al. 2019). Performance in speed-related sports depends mainly on the physiological factors including the athlete's heart performance, lung capacity, muscle mass, body fat, as well as performance economy. At young ages at 10 and 11, male swimmers are similar to female swimmers in all of these physiological factors. As ages increase, the physiological differences between male swimmers and female swimmers become larger, thus leading to the increasing differences in swimming performance in young ages. Knechtle, B. et al. 2016 report that for master freestyle swimmers in 50, 100, and 200m, sex differences reduced from 1986 to 2014 in age groups 30–34 to 75–79 years. In 400m, the gap between women and men reduced in age groups 40-44, 45-49, and 55-59 years. In 800m, sex difference reduced across time in age groups 55–59 and 70–74 years. Similar results were reported for other sports such as ultra-marathon running (Waldvogel, K. J. et al. 2019).

Age speed differences decreased as ages increased until 17–18 years old in a range from 12.79% to −0.37%. For 15 out of 36 female groups, performance had no significant difference at age 16 to 18. Performance of female swimmers became stable earlier than male swimmers. The age speed differences of male swimmers were greater than female swimmers, meaning that male swimmers gain greater improvements in performance than female swimmers over time. In particular, the speed difference gaps between sex groups became greater from younger ages since 10–11-year until 13–14-year groups and became smaller after that. The main reason may be that girls go through puberty and mature earlier in comparison to boys. Similar results on youth elite freestyle swimmers were reported by Senefeld J.W. et al 2019, that swimming performance improved as age increased for boys and girls until reaching a plateau, which initiated at a younger age for girls (15 years) than boys (17 years). Results in Rüst, C. A. et al. 2012 showed that women achieve peak freestyle swim speeds at earlier ages than men. Men were the fastest at age 22–23-years for 100m and 200m; at 24–25-years for 400m and 800m; and at 26–27-years for 50m and 1500m. Women achieved peak freestyle swim speed at age 20–21-years for all distances with the exception of 800m, which is at 26–27-years. The difference in peak freestyle swimming speed decreased as distance increased from 50m to 800m. In Knechtle, B. et al. 2016, it was found that for Olympic champions longer (i.e., 200m and more) race distances were completed by younger (~20-years-old for women and ~22-years-old for men) champions than shorter (i.e., 50m and 100m) race distances (~22-years-old for women and ~24-years-old for men). There was a sex difference in the age of champions of ~2 years, with a mean age of ~21 and ~23 years for women and men, respectively.

Sex differences in shorter distances were smaller than in longer distances in 12 years and younger but became greater than in longer distances at 13 years and after. Age differences in shorter distances are greater than in longer distances. This result is in-line with the finding in recent studies in (Senefeld, J. W., et al. 2019) where it was reported that for all-time top 100 U.S. freestyle swimmers the sex difference in performance at age 18 was larger for sprint events (9.6%; 50–200m) than endurance events (7.1%; 400–1500m). Differences in performance over distances are because sprint swimming performance depends more on strength, explosive power, and anaerobic capacity other than VO2max and body fat as of endurance events in longer distance races. In addition, sex differences in SCM are smaller than in LCM for age groups in ≤12-year, and greater for ≥13-year. Age differences in SCM groups were slightly larger than in LCM groups. This may be because men gain a larger advantage from a greater number of turns, which offer time for muscle recovery. These findings were in-line with the results reported in Koch-Ziegenbein P. et al. 2013 and Wolfrum, M. et al. 2014, in which breaststroke and medley events were examined rather than freestyle. In Wolfrum M. et al 2013, it was reported that elite female and male freestyle swimmers at national and international levels were about 2% faster on 25m compared to 50m course.

The strength of this research was in the data size analysed in the investigation. Using a programming language like Python in statistical analysis enabled a much bigger data set to be imported, including not only selected top elite athletes at national or international levels, but also the large number of ordinary swimmers that are categorized into groups across a number of seasons. It also allowed more flexibility in experimental designs, increase of power, and reliability of statistical analysis and reduction of bias in using a small number of samples. One limitation of the present study is that currently swimmers are grouped by sex/age/course/distance. It would be meaningful if performance/positions (for example top 10%, 25%, 50%, etc.) are adopted as a factor in the grouping, which would make analysis of swimmers at different levels possible. Observations from our analysis show that most statistically exceptional cases come from the group of the youngest age brings, i.e., ≤10 years. One major reason is because the ages of this group compass all ages from 6 years to 10 years, and thus the overall performance varies more than other specific age groups. Future research may split the groups further, or simply remove the group if splitting into specific young age groups is not possible. Some other interesting variables that have not been considered in the present research include the frequency and intensity of training, the number of meets participated in a season, and the starting age of swimmers. In addition, it would be of interest to examine the sex and age differences in other strokes (i.e., breaststroke, butterfly, backstroke, and medley), other older age groups (e.g., 18–20, 20–25, 25–30, 30–40, etc.), and swimmers from other countries.

CONCLUSIONS

By studying all performance data of young Canadian freestyle swimmers from age ≤10 to 18 during season 2008 to 2019 using statistical analysis, numerical results on sex-related differences and age-to-age differences in swimming performance were presented and analysed. Comparing to existing research, our approach used a larger size of data set and considered swimmers at all levels including both elite and ordinary levels. The use of Python as the programming language enables a larger volume of data set being examined, thus allowed more precise, reliable, and flexible statistical analysis to be conducted.

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No potential conflict of interest was reported by the author.

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