Maturational Timing and Swim Performance in Collegiate Female Swimmers

Andrew C. Cornett[1], Alan Duski[1], Sierra Wagner[1], Brian V. Wright[2], and Joel M. Stager[3]

[1] School of Health Promotion & Human Performance, Eastern Michigan University, Ypsilanti, MI, USA

[2] Department of Kinesiology, DePauw University, Greencastle, IN, USA

[3] Counsilman Center for the Science of Swimming, Kinesiology Department, Indiana University, Bloomington, IN, USA

Abstract

The purpose of this study was to determine if maturational timing is related to collegiate swim performance. Maturational timing was estimated using age at menarche (AaM), which was determined retrospectively in collegiate swimmers (N = 273). Each swimmer's best performance during the 2015-2016 NCAA season was obtained from the USA Swimming database and selected based on Power Point Score (PPS), a standardized score given to all performances in the database. Independent samples t tests were used to compare (i) PPS and body mass index (BMI; from self-reported height and weight) between earlier maturing (youngest 33% at menarche) and later maturing (oldest 33% at menarche) swimmers and (ii) AaM and BMI between lower performing (lowest 33% of PPS) and higher-performing (highest 33% of PPS) swimmers. The later maturers performed better than the earlier maturers (PPS 801.7 vs. 759.8, t = 2.10, P = 0.04, d = 0.33) and had lower BMIs (22.5 vs. 23.3 kg/m^2, t = 2.41, P = 0.02, d = 0.36). The higher-performing swimmers were later maturers than the lower-performing swimmers (AaM 14.0 vs. 13.4 years, t = 2.87, P = 0.01, d = 0.45) and had lower BMIs (22.5 vs. 23.2 kg/m^2, t = 1.97, P = 0.05, d = 0.31). These findings suggest that the relationship between maturational timing and swim performance may be due, at least in part, to physical traits common to both later maturers and better performers.

Introduction

Age at menarche (AaM) is a well-accepted and commonly used method for retrospectively quantifying maturational timing (4, 5), with older AaM being associated with later maturation. Interestingly, research has consistently demonstrated that female swimmers are older at menarche – and thus later maturers – than non-athletes (1, 3, 6, 17). But while the later menarche of swimmers is well documented, the sport performance implications are not particularly well understood.

Stager et al. (17) previously investigated the relationship between maturational timing and performance in swimmers. They found (i) that the later-maturing swimmers – as determined by AaM – in their sample performed significantly better than the earlier-maturing swimmers and (ii) that the higher-performing swimmers in their sample were later maturers than the lower-performing swimmers. This study consisted primarily of adolescent, sub-elite swimmers, so the extent to which their findings extend to older, higher-performing swimmers is unknown.

The primary purpose of our study was to build on the work of Stager et al. (17) by investigating the relationship between maturational timing and performance in collegiate swimmers. Based upon previous findings, we hypothesized that the later-maturing swimmers, as a cohort, would outperform their earlier-maturing counterparts, and that the higher-performing swimmers would be later maturers than the lower-performing ones.

Methods

Prior to beginning the study, we obtained permission to collect data on human subjects from our university's human subject committee after the procedures and assurances were reviewed and approved. We recruited collegiate swimmers for participation from NCAA Division I, II, and III swim programs. The participants were all 18 years of age or older, and all provided their informed consent prior to participation.

The recruitment process involved first contacting NCAA head women's swim coaches and asking if they would forward the study description to their swimmers. The study description included a link to an online questionnaire. If a swimmer was willing to participate, she simply had to click on the link and then complete both the informed consent form and the questionnaire. The questionnaire took approximately 5-10 minutes and included questions regarding the participant's height, body mass, race/ethnicity, competitive swimming history, and AaM (as a means of estimating maturational timing).

The primary focus of our study was to compare swim performance between earlier- and later-maturing swimmers. We obtained swim performance data from the USA Swimming performance database. USA Swimming, the national governing body of swimming in the United States, keeps performance records for all its registered members and makes these data available to the public through their website (18). We searched the performance database for every collegiate swimmer having completed the online questionnaire. The majority of swimmers (87%) appeared in the database, and many had dozens of performance records listed. Each swim performance in the database is assigned a HY-TEK Power Point Score (PPS), which is a standardized performance score. In order to reduce the many swim performances into a single performance value, we selected the swim performance during the 2015-2016 NCAA swim season with the highest PPS for each swimmer. The American record in each event corresponds to a PPS of approximately 1100. Thus, while it is technically possible to achieve a PPS over 1100, the scores generally range from 0 to 1100 points, with higher scores indicating better swim performances. Not only did the PPS give us an objective measure of a swimmer's best performance, it also provided us with a means of standardizing performance so as to compare swim performance across different competitive strokes and event distances.

In previous studies investigating maturational timing and performance, researchers formed different groups for maturational timing based on peak height velocity (10), skeletal age (12), and AaM (2, 17). We formed our groups using AaM in a manner consistent with Beunen et al. (2) and Stager et al. (17). The 33% of female swimmers with the youngest AaM were considered to be the earlier maturers whereas the 33% with the oldest AaM were considered to be the later maturers. We compared swim performance – i.e., the best PPS during the 2015-2016 NCAA swim season – between the two groups using an independent samples t test, and used an alpha level of 0.05 to determine statistical significance for this test as well as all other statistical tests described below. Further, we quantified the magnitude of differences between groups using Cohen’s d effect sizes for this comparison and all other comparisons detailed below. We evaluated the effect sizes as trivial (0–0.19), small (0.20–0.59), moderate (0.60– 1.19), large (1.20–1.99) and very large (2.00–3.99) according to Hopkins, Marshall, Batterham, and Hanin (9).

A secondary goal of our study was to better understand why the timing of a particular event – i.e., menarche – is related to performance 5-10 years later. Pre-menarcheal swim training is at the center of one explanation for this relationship. The explanation is that the pre-menarcheal swim training both delays menarche and contributes to better swim performance. Thus, the more training a swimmer does prior to menarche, the later the swimmer will mature and the better the swimmer will perform as an adult. To test this hypothesis, we compared age at initiation of swim training (AIT) between the earlier- and later-maturing groups using an independent samples t test. If this hypothesis is correct, then it seemed reasonable to expect the later maturers to have begun competitive swim training at a younger age than the earlier maturers. However, it is worth noting that AIT is a very rough measure of training load; it does nothing to quantify the training distance and intensity throughout childhood and adolescence. Nevertheless, we used it in this study because it has been previously used when studying maturational timing in athletes (7, 8, 17).

Another explanation for the relationship between maturational timing and swim performance is that there are certain physical characteristics – e.g., less body mass per height and more linear body shape – associated with later maturation that are also associated with better swim performance (11, 13, 17). In order to test the part of this hypothesis related to body mass per height, we used self-reported height and body mass to calculate a body mass index (BMI) value for the swimmers in our sample. Although there is error associated with self-reported height and body mass, data from a nationally representative sample indicate that the correlations between self-reported and measured values for women are in excess of 0.90 (16). And, while reporting bias has been previously demonstrated for self-reported height and body mass, it was for older and overweight women (16), two characteristics that do not apply to our sample. As a result, we used the self-reported values for group comparison. If the relationship between maturational timing and swim performance results from common physical traits associated with later menarche and better swim performance, then we would expect to see lower BMI values in the later-maturing group. In order to determine if this was the case, we compared BMI between earlier and later maturers using an independent samples t test. Further, if this explanation is true, then the best performers in our sample should have later AaM and lower BMI values than their lower-performing peers. To test this, we divided our collegiate swimmers into higher-performing (highest 33% of PPS) and lower-performing (lowest 33% of PPS) groups. We then compared AaM and BMI between the performance groups using an independent samples t test.

Results

Two hundred ninety collegiate swimmers submitted questionnaire responses, although 17 did not provide a response for the questions regarding menarcheal age. The sample primarily identified as White or Caucasian (88.2%), with the remaining respondents identifying as American Indian or Alaskan Native (0.7%), Asian or Pacific Islander (3.5%), Black or African-American (0.7%), Hispanic (2.8%), and Multiple or Other (4.2%). The mean AaM for the collegiate swimming sample, as a whole, was 13.6 years (95% CI, 13.4 to 13.8 years). We only report a single value for AaM here due to the low frequency of occurrence (10 or less) for all races/ethnicities other than White/Caucasian.

Mean values and 95% CIs for the earlier- and later-maturing swimmers for AaM, height, body mass, BMI, PPS, and AIT are shown in Table 1. The later-maturing swimmers had significantly higher PPS (t_{158} = 2.10, P = 0.037, d = 0.33) and lower BMIs (t_{178} = 2.41, P = 0.017, d = 0.36) than the earlier-maturing group. Height (t_{179} = 1.44, P = 0.153, d = 0.21), body mass (t_{178} = 1.38, P = 0.170, d = 0.20), and AIT (t_{179} = 0.31, P = 0.756, d = 0.05) were not different between the earlier- and later-maturing groups.

Table 1. Mean and 95% CI for age at menarche (AaM), height, body mass, body mass index (BMI), Power Point Score (PPS), and age at initiation of training (AIT) for earlier- and later-maturing collegiate female swimmers.

Measure	Earlier Maturers		Later Maturers		Comparison		
	Mean	95% CI	Mean	95% CI	t	p	d
AaM (yrs)	12.1	11.9, 12.2	15.3	15.1, 15.5	25.50	<0.001	3.80
Height (cm)	169.4	168.1, 170.6	170.7	169.3, 172.0	1.44	0.153	0.21
Mass (kg)	66.9	65.3, 68.5	65.5	64.2, 66.8	1.38	0.170	0.20
BMI (kg/m^2)	23.3	22.8, 23.8	22.5	22.1, 22.9	2.41	0.017	0.36
PPS	759.8	729.3, 790.3	801.7	776.1, 827.3	2.10	0.037	0.33
AIT (yrs)	7.8	7.2, 8.3	7.9	7.3, 8.4	0.31	0.756	0.05

Note: USA Swimming HY-TEK Power Point Scores are standardized performance scores that allow for comparison across events. Higher PPS values correspond to better swim performances. The t-ratio, p-value, and effect size are provided for the maturational group comparison.

Mean values and 95% CIs for the lower- and higher-performing swimmers for AaM, height, body mass, BMI, PPS, and AIT are shown in Table 2. The higher-performing collegiate swimmers were older at menarche (t_{159} = 2.87, P = 0.005, d = 0.45), were taller (t_{165} = 4.48, P < 0.001, d = 0.69), and had lower BMIs (t_{165} = 1.97, P = 0.050, d = 0.31) than the lower-performing swimmers. Body mass (t_{165} = 1.15, P = 0.250, d = 0.18) and AIT (t_{163} = 0.13, P = 0.898, d = 0.02) were not different between the lower- and higher-performing swimmers.

Table 2. Mean and 95% CI for age at menarche (AaM), height, body mass, body mass index (BMI), Power Point Score (PPS), and age at initiation of training (AIT) for the lower- and higher-performing collegiate female swimmers.

Measure	Lower Performers		Higher Performers		Comparison		
	Mean	95% CI	Mean	95% CI	t	p	d
AaM (yrs)	13.4	13.1, 13.7	14.0	13.7, 14.4	2.87	0.005	0.45
Height (cm)	168.8	167.5, 170.0	172.7	171.5, 173.9	4.48	<0.001	0.69
Mass (kg)	65.9	64.3, 67.5	67.1	65.9, 68.3	1.15	0.250	0.18
BMI (kg/m^2)	23.2	22.6, 23.7	22.5	22.1, 22.9	1.97	0.050	0.31
PPS	646.6	624.6, 668.5	907.6	895.9, 919.3	20.85	<0.001	3.23
AIT (yrs)	7.7	7.2, 8.2	7.8	7.1, 8.4	0.13	0.898	0.02

Note: USA Swimming HY-TEK Power Point Scores are standardized performance scores that allow for comparison across events. Higher PPS values correspond to better swim performances. The t-ratio, p-value, and effect size are provided for the performance group comparison.

Discussion

The mean AaM for our collegiate swimming sample was 13.6 years, which is well within the range of previously reported values, and well above reported values for non-athletic controls (1, 3, 6, 17). But our primary purpose here was not to verify these well-documented findings; it was to investigate the performance implications of them.

With this in mind, our main finding was that the later-maturing collegiate swimmers in our sample had standardized performance scores that were 5.2% higher than the earlier-maturing swimmers during the 2015-2016 NCAA swim season. The dependent measure here is a standardized performance score though, so we cannot conclude from this that the later-maturing group was 5.2% faster than the earlier-maturing group. In order to determine the typical time difference between groups, we first had to convert the PPSs back into times for each event. To do so, we determined the performance time – in seconds – for PPSs of 759.8 and 801.7 – the mean values for the earlier- and later-maturing groups, respectively – for all NCAA swim events. We then calculated the percent difference in time across all events and found that the performances for the later-maturing group were, on average, 1.68% (95% CI, 1.57% to 1.78%) faster than the performances for the earlier-maturing group. The absolute time difference is, of course, dependent on the event distance and competitive stroke. We can gain a sense of this difference by looking at the 91.44-m (100-yard) race distance. A 1.68% difference in performance during a competitive race at this race distance corresponds to about a second in time, which is roughly equivalent to a body length.

In general, our finding of better performances by later-maturing athletes as compared to earlier-maturing athletes is not novel. Malina et al. (13) previously reported that Olympic-level volleyball players were significantly older at menarche (14.2 years) than high school- and college-level athletes (13.0 and 13.1 years, respectively) in a variety of sports – i.e., golf, volleyball, swimming, basketball, gymnastics, track, and tennis. However, since 'sport' was not held constant, drawing conclusions from this study is somewhat problematic, given that AaM was subsequently shown to differ by sport (1, 6). Further, because competitive level – i.e., Olympic-, college-, and high school-level – is only a rough measure of individual performance, Malina et al. (13) were unable to quantify performance differences to any real extent.

Stager et al. (17) addressed these issues by focusing solely on swimming – a single sport in which individual performance can be easily and accurately quantified – and in doing so, found that the later-maturing swimmers performed significantly better than the earlier-maturing swimmers in their sample. While our study was very similar to the one by Stager et al., both in its conception and outcome, there are some important differences worth noting. First, their sample consisted of both pre-college (69%) and collegiate (31%) swimmers. Since our study was comprised only of collegiate swimmers, our sample was older in age than theirs. The sample composition likely contributed to the fact that the athletes in our sample performed at a higher level than the athletes in their sample. But the point here is not that the sample used by Stager et al. (17) was somehow deficient; it's that our findings are in agreement with theirs despite these differences, and also extend them.

Since the inclusion of current, high-level performers was one aspect of our study that made it unique, it was important to take a closer look at this group. The higher-performing 33% of our swimmers had performances that can be considered national-level performances – based on national meet time standards. When we compare these higher-performers to the lower-performers within our sample, we find that the higher-performers were significantly older at menarche (14.0 vs. 13.4 years) (see Table 2). But this does not mean that an older AaM is a prerequisite for national-level swim performances. In fact, there were 17 swimmers in the earlier-maturing group that were also in the higher-performing group. Thus, relatively early-maturing female swimmers can and do perform at the national-level. However, it remains more common for the best swimmers to be later maturers. Despite being previously shown, the implications of this finding have been widely overlooked, and force an important question: Why is this so?

One explanation for the positive association between AaM and swim performance centers on pre-menarcheal training. The logic is that, as pre-menarcheal training load increases, so too does swim performance and AaM. The key assumption is that physical training during childhood actually *delays* menarche. This explanation obviously only works if the athletes begin training prior to menarche, and this was the case for nearly all (96.7%) of the collegiate swimmers in our sample. So it's at least possible that training delayed menarche for the vast majority of swimmers in our study. However, if this explanation is true, we would also expect to see that the oldest swimmers at menarche began training the earliest. Our data do not show this, though; AIT values for the earlier- and later-maturing groups were not statistically different (7.8 and 7.9 years, respectively) (see Table 1). As a result, our data do not support the argument that pre-menarcheal training contributes to the relationship between maturational timing and swim performance.

An alternative explanation is that there are certain physical traits associated with better swim performance and later menarche (11, 13), and so late maturers are being selected – by themselves or others – for continued participation on the basis of these traits. There is some support for this explanation in the literature. Highly successful athletes and late maturers have separately been shown to have less body mass per height – i.e., lower BMIs – and more linear body shapes than less successful athletes and early maturers, respectively (14, 15). Our data also support this explanation.

When we compared the later maturers to the earlier maturers within our sample of collegiate swimmers, we found that the later-maturing group performed better and had significantly less body mass per height than the earlier-maturing group (see Table 1). And when we compared the higher performers to the lower performers within our sample, we found that the higher-performing group was older at menarche and had less body mass per height than the lower-performing group (see Table 2). Taken together, these findings support the idea that the relationship between maturational timing and swim performance results, at least in part, from physical traits common to both later maturers and better performers.

Summary & Conclusions

The purpose of our study was to determine if maturational timing is related to performance for collegiate female swimmers. Our main finding is that standardized performance scores – i.e., Power Point Scores (PPS) – were 5.2% higher for the later-maturing swimmers in our sample than for the earlier-maturing swimmers during the 2015-2016 NCAA season.

The relationship between maturational timing and swim performance is typically explained in one of two ways. One explanation is that the variables are related because pre-menarcheal swim training (i) serves to delay maturational processes and (ii) contributes to better swim performance as an adult. An alternative explanation is that the variables are related because there are physical traits common to later-maturing women and higher-performing swimmers, and as a result, later-maturing swimmers are being selected for continued participation on the basis of these traits. Our data support the latter explanation rather than the former.

Much of our evidence is correlative, not causative, though, so we cannot say for sure why the timing of menarche is associated with swim performance nearly a decade after the fact. And the cross-sectional nature of our study makes it particularly difficult to draw conclusions and make recommendations from our findings. Nevertheless, we maintain that our findings have important implications for talent identification models and long-term athlete development protocols. But in order to make such recommendations, our cross-sectional analysis needs to be expanded to include longitudinal performance measures.

If we had maturational timing data *and* longitudinal performance records for swimmers, then we'd be in a better position to provide the swim community with evidence-based recommendations. Fortunately, USA Swimming started collecting and storing performance data for all its registered members around 15 years ago. And since many of the collegiate swimmers in our sample have been competing as USA Swimming-registered swimmers since childhood, it's actually possible for us to gather longitudinal performance data for them. This would allow us to determine whether or not adolescent swim performance changes as a function of maturational timing. We recently began the laborious process of collecting childhood and adolescent swim performance records for the collegiate women in this study, and in our companion piece to this manuscript, we will present some preliminary results and discuss their coaching applications. For more on this, please access our coaching application article from the journal's website.

Acknowledgments

We received no external funding for this project.

References

1. Baxter-Jones, A. D. G., Helms, P., Baines-Preece, J., & Preece, M. (1994). Menarche in intensively trained gymnasts, swimmers and tennis players. *Annals of Human Biology*, *21*, 407-415.

2. Beunen, G., De Beul, G., Ostyn, M., Renson, R., Simons, J., & Van Gerven, D. (1978). Age of menarche and motor performance in girls aged 11 through 18. *Medicine Sport*, *11*, 118-123.

3. Constantini, N. W., & Warren, M. P. (1995). Menstrual dysfunction in swimmers: A distinct entity. *Journal of Clinical Endocrinology and Metabolism*, *80*, 2740-2744. Retrieved from press.endocrine.org

4. Damon, A., & Bajema, C. J. (1974). Age at menarche: Accuracy of recall after thirty-nine years. *Human Biology*, *46*, 381-384.

5. Damon, A., Damon, S. T., Reed, R. B., & Valadian, I. (1969). Age at menarche of mothers and daughters, with a note on accuracy of recall. *Human Biology*, *41*, 161-175.

6. Erlandson, M. C., Sherar, L. B., Mirwald, R. L., Maffulli, N., & Baxter-Jones, A. D. G. (2008). Growth and maturation of adolescent female gymnasts, swimmers, and tennis players. *Medicine and Science in Sports and Exercise*, *40*, 34-42. doi: 10.1249/mss.0b013e3181596678

7. Frisch, R. E., Gotz-Welbergen, A. V., McArthur, J. W., Albright, T., Witschi, J., Bullen, B., … Hermann, H. (1981). Delayed menarche and amenorrhea of college athletes in relation to age of onset of training. *Journal of the American Medical Association*, *246*, 1559-1563.

8. Frisch, R. E., Wyshak, G., & Vincent, L. (1980). Delayed menarche and amenorrhea in ballet dancers. *New England Journal of Medicine*, *303*, 17-19.

9. Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*, 3-13. doi: 10.1249/mss.0b013e31818cb278

10. Lefevre, J., Beunen, G., Steens, G., Claessens, A., & Renson, R. (1990). Motor performance during adolescence and age thirty as related to age at peak height velocity. *Annals of Human Biology*, *17*, 423-435.

11. Malina, R. M. (1983). Menarche in athletes: a synthesis and hypothesis. *Medicine and Science in Sports and Exercise*, *10*, 1-24.

12. Malina, R. M., Meleski, B. W., & Shoup, R. F. (1982). Anthropometric, body composition, and maturity characteristics of selected school-age athletes. *Pediatric Clinics of North America*, *29*, 1305-1323.

13. Malina, R. M., Spirduso, W. W., Tate, C., & Baylor, A. M. (1978). Age at menarche and selected menstrual characteristics in athletes at different competitive levels and in different sports. *Medicine and Science in Sports*, *10*, 218-222.

14. McNeill, D., & Livson, N. (1963). Maturation rate and body build in women. *Child Development, 34*, 25-32.

15. Meleski, B. W., Shoup, R. F., & Malina, R. M. (1982). Size, physique, and body composition of competitive female swimmers 11 through 20 years of age. *Human Biology*, *54*, 609-625.

16. Rowland, M. L. (1990). Self-reported weight and height. *American Journal of Clinical Nutrition*, *52*, 1125-1133.

17. Stager, J. M., Robertshaw, D., & Miescher, E. (1984). Delayed menarche in swimmers in relation to age at onset of training and athletic performance. *Medicine and Science in Sports and Exercise*, *16*, 550-555.

18. USA Swimming Web site [Internet]. Colorado Springs: USA Swimming; [cited 2016 Jul 28]. Available from: http://www.usaswimming.org.