USA SWIMMING AGE CLASSIFICATION: ARE CURRENT COMPETITIVE AGE-GROUPS APPROPRIATE?

by

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ABSTRACT

Matching youth sports participants in order to make competition fair and safe is an important goal of sports federations. USA Swimming has established 4 unisex age-groups based on chronological age (CA): 10 years & under, 11-12 years, 13-14 years, and 15 years & over. Due to considerable differences in growth and maturational status among adolescents within any given CA (Baxter-Jones, 1995; Malina & Beunen, 1996), combining swimmers of different ages into groups may not ensure fair competition. Because younger aged or late-maturing swimmers within an age-group are physically behind their same age-group older or precocious peers, the current age-grouping system may discourage them to continue competitive swimming. In addition, there is no historical rationale for the current USA Swimming age classification. The purposes of the study were to evaluate the current age classification enforced by USA Swimming and to provide an analytical rationale in support of the current or alternative age-groupings.

Swim times of the top 100 U.S. women and men swimmers for each age (5 to 20 years) and a group of 21 years and over (a total of 17 separate age-groups for each sex) were acquired through the website of USA Swimming for 2005, 2006, and 2007. Data for each age were pooled over the past three years (2005-2007) and averaged for seven swim events (50-, 100-, and 200-yard freestyle, 100-yard backstroke, breaststroke, and butterfly, and 200-yard individual medley). A 17 × 2 × 7 (age × sex × event) ANOVA with Tukey's post-hoc test was used to analyze the differences in swim time among ages and to propose alternative age-groups.

The study found significant age-related differences in swim performance between each CA up to 15 years old in women and 17 years old in men for most events. Because there were differences in swim performance within the current defined age-groups, stratifying swimmers based on a single age may be a better way for ensuring fairness and equality in competition. The age-related differences in swim time occur later in men when compared with women. This may be due to sex-difference in timing of growth and maturity. The differences between sexes become greater with age but no significant sex-difference was found in 7 years and under age categories. Thus, based upon swim performance, there is no rationale for swimmers under the age of eight to compete in separate unisex categories.

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Chapter 1

INTROFDUCTION

Matching youth sports participants in order to make competition fair and safe is an important goal of sports federations. "Fairness" has been administered by classifying the competitors into groups based on chronological age (CA), a general indicator of developmental status. USA Swimming has adopted four unisex age-groups for championships. Each group is composed of plural CA categories: the ages of 10 years and under, 11-12 years, 13-14 years, and 15 years and over, but there seems to be no rationale behind this age-grouping. Although 2-year duration of CAs appears to be a relatively narrow range, it may be that fairness and equity in competition are compromised by combining plural CAs into a group. The considerable differences in maturity status among the swimmers within age-groups may result in great size and strength differences and cause maturity-based performance outcomes. For example, in the 11-12 years old group, 12-year-old swimmers are more likely taller, bigger, and stronger, and thus, faster than their 11-year-old counterparts. Therefore, younger swimmers or late maturers in an age-group may be disadvantaged and may experience a lack of success, failure, or frustration from the current age-groupings. Because they are physically behind their same age-group precocious peers, combining young swimmers of different CAs into a multi-CA group may discourage them from continuing competitive swimming. Are the current age-groupings in swimming enforced by USA Swimming truly equalizing competition and minimizing the influence of maturational differences? This question prompted this investigation.

Statement of the Problem

The problems of this study were to ascertain the adequacy of the current age-group classification enforced by USA Swimming by evaluating and comparing swim performance across ages as well as within age-groups and to provide an analytical rationale in support of the current or alternative age-groups.

Purpose of the Study

It was anticipated that information obtained in this study would provide an analytical assessment of the current age-groups adopted by USA Swimming and also propose potential alternative age-groups. This study was intended to propose approaches regarding: where the line for age-grouping should be drawn among CA categories; and whether or not there is a better or more streamlined way to assure fair competition in competitive age-group swimming. If there is no significant difference in swim performance between any CAs, it would be proposed to combine the CA categories into a multi-CA group, and vice verse.

Significance of the Study

It is the typical American lifestyle to encourage children and adolescents to participate in physical activity and exercise. Awareness of increases in pediatric and adolescent obesity and positive social and developmental attributes of sports appear to make youth sports increasingly popular and an important source of physical activities in the U.S. Available data since the 1970s show that the estimated number of high school athletes has gradually increased despite a decline in the number of students enrolled in high school (Malina, Bouchard, & Bar-Or, 2004; Seefeldt, Ewing, & Brown, 1996). In the 1990s, 55 percent of youths aged 10 to 18 years participated in a non-school sport activity (Seefeldt et al., 1996). More than 38 million children and adolescents participated in an organized sports team in 2000, while 33 million youth athletes participated in 1997 (National Council of Youth Sports [NCYS]; 2001).

Youth sports fundamentally contemplate enhancing participation and allowing participants to enjoy positive experiences, thereby developing patterns of physical activity that carry over into adulthood (Anderson & Ward, 2002). It has been demonstrated that a child's continued involvement in youth sports is associated with the perceived benefits of participation, including the opportunity for social interaction and the development of social relationships, enjoyment, and competence (Carpenter & Scanlan, 1998; Ebbeck & Weiss, 1998). In addition, creating a competitive environment for children in which they feel competent will not only increase commitment to the sports (Carpenter & Scanlan, 1998) but have a significant impact on a child's self-esteem (Ebbeck & Weiss, 1998). Although there are, however, many participants at the novice levels, the social issue of discontinued participation known as "dropouts" has always existed on the logistical side of youth sports. Research states that 35 percent of youth participants withdraw annually from organized sports, and up to 70 percent drop out of sports by the age of 18 years (Brady, 2004; Gould, 1987; Seefeldt et al., 1996). These have been thought to be associated with a feature of competitive sports in that, as the level of skill and competition increases, sports become more exclusive, selective, and regulative. Petlichkoff (1996) has reported that adults' (coaches') excessive emphasis on winning discourages young athletes from competing, achieving, being successful, and continuing to choose the sport. Negative reinforcement and coaching manners and/or over-demand and -pressure from coaches and parents on children can be other reasons (Martens, 1996). Hardy (1986, p. 157) maintains that "there is nothing wrong with competition per se. What is wrong is the way in which children's competition is sometimes used by adults to achieve their own aims, regardless of whether these aims are coincident with those of the children."

On the other hand, substantial literature has proposed mismatched youth competitors as a possible major cause of dropouts, that is, classification systems may discourage children from continuing sports (Baxter-Jones, 1995; Caine & Broekhoff., 1987; Malina & Beunen, 1996; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002; Roemmich & Rogol, 1995; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007). Chronological age (CA) or grade in school has been commonly used as a criterion of classification systems. The most common practice is to classify participants into CA-groups based on 2 year-intervals (Anderson & Ward, 2002; Malina & Beunen, 1996). Whereas the improvement in physiological functions associated with sports performance occurs with CA, it is well known that CA is of limited utility in the assessment of growth and especially maturation (Beunen, 1989; Gallahue, 1989; Malina, 2000). It has been argued that biological maturity status must be considered in the evaluation of performance capacities of growing children and in classification systems. Early-maturing children are typically advanced in their physical growth at all ages (Malina et al., 2004). However, there is also the fact that the implementation of biological age or maturity-based interventions is beyond the resources of sport-governing bodies or youth sport organizations (Mirwald et al., 2002). The methods to assess maturity are costly, intrusive, and sex-specific and also require invasion of individual privacy (Anderson & Ward, 2002; Malina, 1988; Mirwald et al., 2002). Also, growth and maturation are continuous processes and must be measured or observed at intervals over time, susceptible to measurement errors, and may lead to confusion with a child classified into different groups. These may be inappropriate and stressful for youth athletes as well as the person at the registration desk. For these potential reasons, CA is the common classification criterion and usually the only one operable in the field setting.

In competitive swimming 4 unisex CA-groups composed of at least 2-year intervals have been adopted by USA Swimming. However, due to considerable age and sex differences in growth and maturational status among children within a single CA (Malina, 1988; Malina, 2000; Mirwald et al., 2002), a major concern for the custom age-groupings in swimming arises from combining adolescent swimmers of different CA categories into groups or a group. Although matching contestants during childhood and adolescence for both fair and safe competition is difficult, swimming, as Stevens (2008) mentioned, may be failing by not providing appropriate levels of competition. The younger swimmers within each age-group are consistently denied the opportunity to perform and earn the rewards at the next competitive level causing a possible decrease in motivation for continued sports participation (Baxter-Jones, 1995; Stevens, 2008). Factors such as unfair competition could result in a child no longer wishing to participate in sports (Baxter-Jones, 1995). Thus, one of the causes of discontinued enrollment in age-group swimming is ascribable to improper age classification systems. It is important to provide youth swimmers with meaningful opportunities to compete, achieve, succeed, and continue to choose the sport of swimming.

With the growing controversy over the classification systems for youth competition and the lack of scientific rationale behind the customary age-groups in swimming, an in depth analysis of partitioning age-group swimmers is thought to be necessary. The need for a more systematic understanding of age-group classification is essential to further development and prosperity of age-group swimming. In the present study, an effort is made to evaluate the current age classification enforced by USA Swimming by analyzing performance among swimmers grouped by single CA categories. Also, a statistical rationale for proposing alternative age-groups is provided.

Delimitations

The study was delimitated as follows:

1. Swim times of the top 100 U.S. women and men swimmers from the ages of five to twenty years as well as an age-group of 21 years and older were used.
2. A group of swimmers aged 21 years and older is determined as the highest performance group in the U.S.
3. Members of USA Swimming were used.
4. 50-, 100-, and 200-yard freestyle, 100-yard backstroke, breaststroke, and butterfly, and 200-yard individual medley were used for the comparison among all ages.
5. Complete data for all ages and events were utilized over the past 3 years between January 1st of 2005 and December 31st of 2007.
6. Data were acquired through USA and Indiana Swimming websites which are accessible to the public.

Limitations

The results from this investigation were interpreted considering the following limitations:

1. Sampling data of the top 100 swimmers in each age may not be representative of the overall swimming population in the U.S.
2. No assessment was made of maturational status and anthropometric variables of samples.
3. Swim times cannot necessarily address growth and development in swimmers.
4. Data and results do not ensure the link with growth and development as causative.

Assumptions

The basic assumptions of this study are:

1. The top 100 U.S. swimmers in each age represent the overall swimming population in the U.S.

2. The increase in body size and the maturation of the endocrine, nervous, muscular, and cardiovascular systems associated with swim performance are related to the increase in CA.
3. Data were assumed to be complete and accurate as obtained by USA Swimming.
4. The higher rankings of swimmers during early adolescent period are thought to be associated with early/advanced-maturing.
5. Differences in swim performance are not due to differences in training or training characteristics but to differences in growth and development.

Hypotheses

The specific research questions were as follows: 1) whether or not the current age-groups established by USA swimming are appropriate as a means of providing fair competition; 2) whether or not more appropriate competitive groupings, based upon CAs, can be proposed; 3) whether or not sex-specific age-grouping systems are necessary due to sex-differences in timing of the adolescent growth spurt and maturity; and 4) whether or not the age of eight and under (prebubertal) swimmers should be classified into separate unisex categories. The study was designed to test the following hypotheses:

H_1: There is a significant difference in swim performance among CAs.

H_2: The differences in swim time between adjacent ages become smaller with the increase in CA.

H_3: There is a significant difference in swim performance within the current age-groups.

H_4: The difference in swim performance between CAs within age-groups can be reduced.

H_5: Age-groupings in women swimmers are different from those in the men.

H_6: There is no significant sex-related difference of swim performance in 8 years and younger age-categories.

Definitions of Terms

The following terms are defined to clarify their use in the study:

Adolescence. In terms of chronological age, adolescence occurs across the approximate age range of 10 to 20 years old. It can be divided into preadolescent (approximately age 10-12 years in girls and 11-13 years in boys) and postadolescent periods (approximately age 12-18 years in girls and 14-20 years in boys). Periadolescence is a new term describing the phase from age 8 to 10 years in girls, and 9 to 11 years in boys, before they are clearly preadolescent (Gillen, 2007). Biological age through assessment of morphology, skeletal maturation, dentition, and sexual maturation can be used to assess the progress of individuals toward maturity (Gallahue, 1989). Adolescence is also used synonymously with puberty and refers to the psychological changes associated with puberty (Marshall & Tanner, 1986). According to the World Health Organization (http://www.who.int/en/), the adolescent period is between 10 and 18 years old, but 8 to 19 years old in girls and 10 to 22 years in boys are more appropriate as limits for normal variation in the onset and termination of adolescence.

Age-group swimming. A swimming category consists of swimmers under the age of 15 years. In the U.S., the category is divided into 3 groups: age 10 years and under, 11-12 years, and 13-14 years groups.

Birth. Day 0 (Malina et al., 2004)

Biological maturation. This must satisfy the following conditions: it must reflect changes in biological characteristics, reach the same final stage in every individual, show a continuous smooth increase although most often discrete stages on this continuum can be identified, be applicable throughout the maturation process, and be independent of size (Beunen, 1989).

Childhood. The 1st birthday (day 365) to the start of adolescence (Malina et al., 2004). According to Malina et al. (2004), childhood is often divided into the following categories: early childhood (the preschool years, 1 to 4 years of age; 1 to 4.99 years), and middle childhood (elementary school years, into 5th and 6th grade; 5 year to the beginning of adolescence). Gallahue (1989) defines childhood as the period between approximately age 2 and 10 years. It can be divided into three stages: toddler (age 2-3 yrs), early childhood (age 3-5 yrs), and middle/late childhood (age 6-10 yrs). Biological age through assessment of morphology, skeletal maturation, dentition, and sexual maturation can be used to assess the progress of individuals toward maturity (Gallahue, 1989).

Development. 1) In biological contexts, development is the differentiation of cells along specialized lines of the function and functional refinement of body systems; 2) In behavioral contexts, it is the development of competence in a variety of interrelated domains as a child adjusts to his or her cultural milieu (Malina et al., 2004)

Fairness. The quality of being fair (Longman, dictionary of contemporary English; http://www.ldoceonline.com/)

Growth. A process involving hyperplasia (increase in cell number), hypertrophy (increase in cell size), and increase in intracellular materials (Beunen, 1989). That is, growth refers to measurable changes in size, physique, and body composition, and various systems of the body. The processes of growth and maturation are intimately linked because differential growth creates form (Falkner & Tanner, 1978).

(Adolescent) Growth spurt. An acceleration followed by a deceleration of growth in most skeletal dimensions and in many internal organs (Marshall & Tanner, 1986). The rates of growth in both stature and weight increase or accelerate (Malina et al., 2004).

Age at peak height velocity. An indicator of somatic maturity in longitudinal studies of adolescence. Age at maximum rate of growth in stature during the adolescent spurt (Malina et al., 2004).

Infancy. The 1st year of life excluding the 1st birthday: day 0 to day 364 (Malina et al., 2004). This is a period of rapid growth in most bodily systems and dimensions and of rapid development of neuromuscular system. Infancy can be divided as follows: perinatal period (around the time of birth, the 1st week), neonatal period (the 1st month of life), and postnatal period (the remainder of the 1st year).

Maturation. The successive tissue changes that take place until a final form is achieved. Maturation implies specialization and differentiation of cells (Acheon, 1966) and progress toward maturity (Malina et al., 2004). Maturation is a process and maturity is a state.

- Level of maturity in time. Maturity status at a given age.
- Level of maturity in timing. Referring to when maturational events occur.
- Level of maturity in tempo. The rate at which maturation progresses.

Maturity status. With a comparison between biological age (BA) and chronological age (CA), children/adolescents are classified into three maturity statuses (Malina et al., 2004).

- BA > CA by more than 1 year ---- advanced or early maturation (early maturers)
- BA = CA within ± 1 year ---- average, also called "on time"
- BA < CA by more than 1 year ---- slower or late maturation (late maturers)

Peak height velocity (PHV). The maximum velocity of growth in stature (cm) plotted against age (Malina et al., 2004).

Prepuberty. This simply means that the children show no overt manifestations of maturational indicators, being in the 1st stage of secondary sex characteristics (Marshall & Tanner, 1986).

Puberty. This refers collectively to the morphological and physiological changes that occur in the growing boy or girl as the gonads change from the infantile to the adult state (Marshall & Tanner, 1986). It is a transitional period between childhood and adulthood. This includes the appearance of secondary sex characteristics, maturation of the reproductive system, and the adolescent growth spurt in addition to psychological behavioral changes (Malina et al., 2004).

Senior-group swimming. A swimming category consists of swimmers of all ages but the category is specified as swimmers aged 15 years and over. This category is also called 'OPEN' which means all members.

USA Swimming. The National Governing Body for the sport of swimming in the United States. USA Swimming is a 300,000-member service organization that promotes the culture of swimming by creating opportunities for swimmers and coaches of all backgrounds to participate and advance in the sport through clubs, events and education (http://www.usaswimming.org).

Youth sports. In American culture, youth sports has been applied to any of the various athletic programs that provide a systematic sequence of practices and contests for children and youth (Seefeldt, Ewing, & Walk, 1991)

Chapter 2

REVIEW OF THE RELATED LITERATURE

Fair and equitable competition in youth sports remains a noteworthy but unresolved debate as the issues surrounding classifying child and adolescent athletes are evident in recent literature. In this chapter, the literature addressing attempts, approaches, and controversies regarding classification systems in youth sports is first reported, and issues on the current age classification of competitive swimming in the U.S. are centered. The following is a topical outline: 1) Classification Systems in Youth Sports, a) Skeletal Maturity, b) Sexual Maturity, c) Somatic Maturity, d) Dental Maturity, e) Neuromuscular Maturity (Motor Development), f) Overview; 2) Variation within Maturity Indicators Relative to CA; 3) Classification Systems in Swimming; 4) Preliminary Results; 5) History of Age-Group Swimming in the U.S.; 6) Summary.

Classification Systems in Youth Sports

Youth sports have many participants and many levels of competition. This raises the necessity of a structure for competition and a special regulation on participation. Consequently, participants must compete based on classification, referring to the way that participants are grouped for competition. Classification systems in competitive youth sports are an important means of matching contestants to equalize competition, to enhance the chances of success for all participants, and to reduce the risk of injury associated with size and strength mismatches (Malina & Beunen, 1996; Mirwald et al., 2002). In individual sports such as swimming, track & field, and athletics, the primary goal of classification systems is to provide fair competition or "a level playing field." For example, many sport events are partitioned by sex; wrestlers are grouped by body weight; youth swimmers and runners are classified by chronological age (CA). Furthermore, athletes with a disability compete based on their ability and/or their disability characteristics.

CA and sex have been the most common criteria in attempts to classify youth athletes into homogenous groups in individual sports. This may be because the increase in body size and the maturation of the endocrine, nervous, muscular, and cardiovascular systems associated with sports performance are proportional to the increase in CA (Roemmich & Rogol, 1995). In addition, it is not difficult for sport-governing bodies or youth sports organizations to obtain information of CA and sex from each athlete. However, it has been revealed that maturational assessments provide better indices of physical status than CA, and they are the recommended method of classifying children in competitive sports (Caine & Broekhoff, 1987; Gomolak, 1975; Haffner, 1982). As long ago as 1905, the utilization of maturity indicators as classification criteria was advocated because of the closer association of physiological functions related to sports performance with biological maturation rather than CA (especially during puberty and adolescence; Crampton, 1908; Pryor, 1905; Rotch, 1909). For instance, Crampton (1908) applauded the use of physiological age based on the assessment of pubic hair development for the classification of adolescent schoolboys in athletic programs, while Rotch (1909) emphasized the use of anatomical age using X-ray and carpal development. The three most common indicators of maturity status are skeletal, sexual, and somatic maturity (Malina, 1988). In addition, dental and neuromuscular maturities are suggested as other possible classification criteria. The following are brief descriptions and limitations of each potential classification criterion.

a) Skeletal Maturity

The first potential criterion for youth athlete classification is skeletal age (SA) based on the assessment of bones at the hand-wrist region with X-ray or radiographs. This is suggested as perhaps the best method to assess progressive maturation in a growing child because the developing skeleton (maturity status of ossification) is irreversible and easily viewed on radiographs (Armstrong & van Mechelen, 2000; Beunen, 1989). In addition, it has been demonstrated that hormone levels and several performance variables are highly related to SA due to its continuous rather than discrete nature since skeletal maturation spans the entire growing period (infancy to young adulthood; Beunen, 1989; Johnston, 1962; Malina et al., 2004). There are three main techniques for determining SA; Greulich-Pyle (GP) method with atlas techniques (Greulich & Pyle, 1959; Greulich, Pyle, & Waterhouse, 1971), Tanner-Whitehouse (TW) method with a bone-specific approach (Tanner, 1962; Tanner et al., 1975; Tanner, Whitehouse, Marshall, Healy, & Goldstein, 2001), and Fels method with computer-assisted procedures (Roche, Chumlea, & Thissen, 1988). The GP method consists of a series of plates (roentgenograms), hand/wrist X-ray representatives of the maturity status of bones for boys and girls at a given age, published in an atlas. SA is rated by comparing the individual's X-ray with those in the atlas. In the TW method, a point scoring system, each of 20 bones of the hand and wrist in a child is first graded on a scale corresponding to successive levels of skeletal maturity at specific CA and is next converted to a maturity score. The summed scores of each bone are then used to convert to an SA. The Fels method statistically weights the contribution of specific bone maturity indicators depending on the sex and age of a child and calculates the SA at a point in time. The Fels method also provides a standard error for the assessment. SA methods have been improved with the use of dual energy x-ray absorptiometry or magnetic resonance imaging (MRI) providing the potential for more rapid and accurate assessments and the elimination of interobserver variability in assessments (Braillon et al., 1998). Also, MRI has no radiation risk and offers an alternative as a non-invasive method of SA examination (Dvorak, George, Junge, & Hodler, 2007).

The drawbacks of using SA as a classification criterion are a yearly radiation dose, the need for a competent assessor and transportation to a proper facility, and the cost of the radiograph and assessments (Caine & Broekhoff, 1987; Haffner et al., 1982; Roemmich & Rogol, 1995). Bull, Edwards, Kemp, Fry, and Hughes (1998) have demonstrated a large scale comparison (N = 362) of SA using GP and TW methods. There is the discrepancy between methods (Range: 2.28 to -1.52 years) and intra-observer variation (S.D.: 1.16 and 0.71 for GP and TW methods, respectively). In addition, Bland–Altman analysis indicated the significant difference of SAs from zero between methods ($p < 0.01$), a result similar to that of other studies (Milner, Levick, & Kay, 1986; King, Steventon, & Sullivan, 1994). The authors have concluded that using these assessments may not be preferable in clinical practice. A study comparing SAs among GP, TW, and Fels methods revealed that the three methods do not provide the same estimate in adolescence (Kujawa, 1997). These disparities among methods are attributed to the reference values used for each method and different methods deriving an assessment of skeletal maturity

(Malina et al., 2004). Lastly, Loder et al. (1993) have investigated the applicability of the GP method to black and white children in 1990s since the roentgenograms used for the method were obtained from only white children of upper socioeconomic status in limited mid-western areas during the 1930s. The study found that the atlas was not applicable to all children and appropriate skeletal age standards are needed for SA assessments of different generations.

b) Sexual Maturity

Puberty is a transition period between childhood and adulthood including appearance of secondary sex characteristics (SSCs), maturation of the reproductive system, and the growth spurt, besides psychological and behavioral changes (Armstrong & van Mechelen, 2000; Malina et al., 2004). Based on the development of pubic hair (PH) and genitals (G) in boys and the development of PH and breast (B) in girls, the sexual maturity status of a child is rated by standardized photographs. By visual inspection on clinical examination, the child is categorized into one of five or six stages. The first stage represents the prepubertal state with the absence of overt manifestation of each SSC. The second to fourth stages correspond to pubertal state: the 2nd stage (early puberty) with the initial overt development of each characteristic and the 3rd and 4th stages (midpuberty) with continued maturation of each SSC. The 5th stage (post puberty) displays adult or mature state. Stage 6 in PH marking the expansion of PH upwardly in the midline of abdomen is occasionally used (Van Wieringen, Wafelbakker, Verbrugge, & DeHaas, 1971).

Limitations of evaluating SSCs are the necessity to disrobe during determination, the invasion of the participant's privacy causing the participant undue stress, and the requirement of a highly trained assessor (Caine & Broekhoff, 1987; Haffner et al., 1982; Roemmich & Rogol, 1995). To reduce the invasion of privacy, self-assessment has been suggested in previous studies. The correlation between self-assessment and physicians' assessments of SSCs has been reported as r = 0.63-0.93 and 0.59-0.88 in girls and boys, respectively (Duke, Litt, & Gross, 1980; Marcela, Matsudo, Keihan, & Matsudo, 1994; Morris & Udry, 1980; Neinstein, 1982). Although they appear to be moderate to high, for the individual assessing SSCs it is often difficult to ascertain whether a child is at the end of a stage or beginning the next stage (Roemmich & Rogol, 1995). There is also a need for observations over relatively short intervals during puberty, i.e., 3 to 6 months. The development stages are argued to be fairly crude, discrete milestones in a continuous process (Beunen, 1989). Furthermore, indicators of maturity status and progress are limited to the pubertal phase giving limited applicability over the course of the child's growth, in contrast to SA (Beunen, 1989; Malina et al., 2004).

Age at menarche as well as the onset of menarche is also used as a maturity indicator of adolescent girls and adult women. There are several methods for estimating age at menarche. The most common method called the prospective or longitudinal method is to interview girls or their mothers on each occasion as to whether menarche has or has not occurred or when it occurred with 3- or 6-month intervals (Beunen, 1989; Malina et al., 2004). A statistical method, the status quo method, is based on probit analysis (Wellens & Malina, 1990) and two pieces of information, the exact age of a girl and menarcheal status (whether pre or post). For postmenarcheal adolescents, the age is retrospectively estimated by interrogating a girl or her mother. Each of the women tries to recall the age at which they attained menarche to the nearest month as accurately as possible. A scale based on the onset of menarche has also been used to determine developmental age (Gomolak, 1975; Haffner et al., 1982). The developmental age used was based on the concept that all girls are at approximately the same stage of physical development once menarche has been reached. Besides invasion of privacy, the limitation of this approach arises from error in recall due to the retrospective methods (Beunen, 1989). Moreover, since menarche is a late maturational event occurring while most girls are in stage 4 of B and/or PH developments (Malina et al., 2004; Marshall, 1978), it is only very narrowly applicable to the classification problem of adolescent girls. No easily recognizable developmental trait is available for boys.

c) Somatic Maturity

The third indicator for assessing maturity status is age at peak height velocity (PHV) of growth. A longitudinal approach to adolescence is required for determining the age at maximum rate of growth in height during the growth spurt (Malina et al., 2004). This approach spans the interval from 9 to 18 years old. This indicator also serves as a landmark against other body dimensions and physical performance. For example, the age at peak weight velocity and peak strength development in both sexes and menarche in girls has been revealed to occur after PHV (Iuliano-Burns, Mirwald, & Bailey, 2001). Allowing for variation among samples and in methods of estimating age at PHV, the mean ages at PHV in girls vary between 10.9 and 12.2 years old, while those in boys are between 12.9 and 14.4 years old on the basis of the data of numerous previous studies (Berkey, Wang, Dockery, & Ferris, 1994; Beunen & Malina, 1988; Bielicki, 1975; Bielicki, Koniarek, & Malina, 1984; Bock & Thissen, 1980; Guo, Siervogel, Roche, & Chumlea, 1992; Hauspie et al., 1980; Lago, Gasser, Prader, Stuetzle, & Huber, 1978; Ledford & Cole, 1998; Lindgren, 1978; Malina, 1988, Malina et al., 1997; Malina & Beunen, 1996; Malina et al., 2004; Mirwald, Bailey, Cameron, & Rasmussen, 1981; Preece & Baines, 1978; Tanner, Whitehouse, & Takahashi, 1966; Tanner, Whitehouse, Marubini, & Resele, 1976; Taranger, Engström, Lichtenstein, & Svennberg-Redegren, 1976; Thissen, Bock, Wainer, & Roche, 1976; Wafelbakker, 1970; Zacharias & Rand, 1983). Reported standard deviations (SD) for the mean ages at PHV range from 0.7 to 1.3 years old in both sexes. It has been estimated that PHV occurs, on average (mean ± SD), 12.0 ± 1.0 years old in girls and 14.0 ± 1.0 years old in boys (Malina et al., 2004). Based on the estimated mean age at PHV based on previous reports, girls and boys who attain PHV before 11.0 and 13.0 years of age, respectively, would be classified as early maturing, whereas attaining PHV after 13.0 and 15.0 year of age, respectively, would be classified as late maturing. In addition, children attaining PHV 'on time' would be average maturing.

The drawback of using age at PHV is the inconvenience of having to follow children over several years at regular intervals to define this pubertal event accurately. Also, growing children spanning the age of 9 to 18 years are assigned to only three groups (early, average, and late maturing) possibly resulting in improper or unfair competition to young athletes as discussed earlier.

d) Dental Maturity

The time or age of eruption of the deciduous and permanent teeth has been determined for the assessment of dental maturity (Demirjian, 1986; Demirjian & Goldstein, 1976; Tanner, 1980).

Calcification of permanent teeth is used to estimate stage of dental age (DA). The principles and procedures of DA are similar to the assessment of the SA, TW method. It requires an X-ray of the 7 teeth in one quadrant of the mouth (2 incisors, the cuspid, 2 premolar or bicuspids, and the 1st and 2nd molars) and, it is based on the features common to a tooth (Demirjian, 1986). Using the specific stage of each tooth, point scores are assigned to each stage, and the sum of the point scores is converted to DA. However, dental maturity is not well correlated to the 3 common indicators described above. Moreover, it has reported that there are difficulties in using dental maturation as the assessment of biological age due to no significant sex differences in the timing of deciduous dental development (Roche, Wainer, & Thissen, 1975). Thus, the DA assessment has been an exception as a classification criterion with no practical instance other than a rough proxy for CA when the later is unknown.

e) Neuromuscular Maturity (Motor Development)

The neuromuscular maturity, often meaning 'motor development', of children has been considered as an alternative classification criterion because the development of strength, motor performance, and aerobic power in children is proportional to the timing of the adolescent growth spurt and also CA (Beunen & Malina, 1988; Heras Yague & de la Fuente, 1998; Malina et al., 2004; Roemmich & Rogol, 1995). Motor development is the sequential, continuous age-related process whereby movement behavior changes (Haywood & Getchell, 2005). The assessments include measures of performance-related fitness, such as dashes, jumps, and agility run, and health-related fitness, such as distance runs, flexibility, sit-ups, and body fatness. Previous studies have attempted to develop a system for the classification of children into fair competitive groupings based upon vertical jump or grip strength which requires simple, easy measurements (Anderson & Ward, 2002; Backous, Friedl, Smith, Parr, & Carpine, 1988; Ward, Purnell, & Ross, 1981). However, physical performance tests are within individuals' control and can be largely influenced by motivation. There is potential for athletes to cheat by holding back during early levels of competition so that they can be in a favorable position against less skilled counterparts. Thus, when performance tests are applied to classification systems, the individuals could purposefully manipulate performance to change classification level. Although it appears that improvements in neuromuscular performance in boys are subsequent events of age at PHV and growth of skeletal muscle mass, those in girls show variability. Thus there is the limited applicability of neuromuscular maturity to classification criteria for girls (Beunen & Malina, 1988; Heras Yague & de la Fuente, 1998; Malina & Beunen, 1996; Malina et al., 2004; Roemmich & Rogol, 1995).

f) Overview

The fact that there is no practical, universal classification system for children in non contact/collision youth sports beyond CA (Mirwald et al., 2002) indicates CA is the only operable sports classification criterion in the field setting. In addition to cost, complexity, and safety of maturity assessments, availability and validity of methodology all act to limit their utility for youth sports classification. Although anthropometric measurements, such as height and weight, might be considered as one of the criteria due to no cost, simple measurement, and safety, they can possibly confuse children and sports organizations. At the age of PHV, children grow, on average, 12 to 15 cm per year in stature (Lindgren, 1978), while peak weight velocity has been reported as about 10 kg per year (Malina et al., 2004). As a result, a child may be classified into different groups from one competition to another competition. Therefore, since CA is the only criterion which does not require any particular measurement, it alone has been employed for youth sports classification.

Variation within Maturity Indicators Relative to CA

Considerable maturational differences of children within a single CA have been revealed (Malina et al., 2004). Table 1 demonstrates that within each CA the range of SA is approximately eight times as great as that of CA. Children vary considerably in biological maturity (skeletal maturity) although they are chronologically homogeneous. From this discussion, it is clear that biological maturity status should be considered in the evaluation of performance capacities of growing children, thus in classification systems. Although sports participation based on maturational assessments appears to be substantially recommended, especially during puberty and adolescence (Baxter-Jones, 1995; Caine & Broekhoff, 1987;

Malina & Beunen, 1996; Mirwald et al., 2002; Roemmich & Rogol, 1995; Sherar et al., 2007), there is little evidence of this practice using sexual maturity indicators in contact and collision sports (Gomolak, 1975; Haffner et al., 1982) and no evidence of the practice in individual sports has been reported. There is no indication in the literature that skeletal maturity (or SA), the potentially best maturity-based criterion, has been employed for sports classification systems. This situation could be explained by the impractical nature of SA assessments with high expense and exposure to radiation. On the other hand, an approach by the New York State High School Athletic Association (Gomolak, 1975; Haffner et al., 1982; Willie, 1982) indicated that sexual maturity-based classifications using the Tanner stages (Tanner, 1962) reduced injury rates, i.e., reduced mismatching youth athletes. However, because of the additional classification criteria associated with sports performance, such as physiological factors (strength, endurance, and agility) and achieved skills, used for the approach besides the Tanner stages, the findings must be interpreted with caution. Whether or not SSCs assessments result in equalizing competition and/or reducing injury rates, thus, have not been corroborated in the literature.

Table 1. Variation in chronological age (CA) and skeletal age (SA) in a sample of children observed annually from six to eight years of age.

Girls (n = 22)				Boys (n = 18)			
CA		SA		CA		SA	
mean ± SD	range	mean ± SD	range	mean ± SD	range	mean ± SD	range
6.2 ± 0.2	6.00-6.62	6.6 ± 1.1	4.22-9.24	6.2 ± 0.1	6.00-6.41	6.0 ± 0.8	4.03-7.76
7.2 ± 0.2	7.01-7.63	7.5 ± 1.1	4.93-10.08	7.2 ± 0.1	7.02-7.45	7.1 ± 0.9	5.09-8.94
8.2 ± 0.2	8.00-8.59	8.6 ± 1.1	5.71-10.61	8.2 ± 0.1	8.01-8.46	8.1 ± 0.8	6.35-9.28

Data were derived from Malina, R. M., Bouchard, C., & Bar-Or, O. (2004)

Variation within each maturity indicator or its stage may have also confounded its utility as classification criteria. It has been evident that grouping children by maturity assessments to the exclusion of CA is of limited utility (Haschke, 1983; Malina et al., 2004). Table 2 shows the range of CA within each stage of genital maturation in a sample of boys. This procedure may reduce variation within the sample to some extent, but the variation independently associated with CA is overlooked. In other words, children within an evaluated maturity stage may be biologically and physically homogenous, but their mental level or competitive experience may not be homogeneous. For instance, when one applies the assessment of genital development to classification systems, an 11-year old boy in G3 must compete against a 14 year-old boy (Table 2). The maturity assessment may confront early-maturers with a psychological disadvantage, while late-maturing children would resent being forced to compete with chronologically younger peers as Caine & Broefhoff (1987) reviewed. The importance of maturity assessment to the psychological well-being of young athletes must be highlighted. Since the same applies to the use of other SSCs and age at PHV, it is postulated that an increase in psychological insult to children might accompany the use of maturity assessments. Furthermore, although considerable maturity-related differences in body size, such as height, weight, and skeletal muscle mass, among children within any given CA, are well acknowledged as a problem, this problem may not be improved by the use of maturity-based classification. Table 3 shows the same sample of boys and girls (194 and 207, respectively) classified into CA and somatic maturity groups. The differences in height and weight between two adjacent CA groups are, on average, smaller than those between two somatic maturity stages (Table 3). If some ages are combined into a group, the difference seen in somatic maturity group could be more emphasized. This does not resolve the technical issues of utilizing CA and may explain the limited utility of maturity indicators for classification criteria.

Table 2. Range of chronological age (CA) within each stage of genital maturation in a sample of boys.

Genital stage	CA (yrs)
G1	10.00-12.08
G2	10.75-13.17
G3	11.75-14.58
G4	12.83-14.83
G5	13.75-14.92

Date were derived from Haschke (1983)

Table 3. Comparison of differences in height and weight within chronological age (CA) groups with those within somatic maturity stages (N = 401, 194 boys and 207 girls).

CA group

Boys	n	Height	Diff.	Weight	Diff.
8 yrs	11	129.2		26.8	
9 yrs	39	137.8	8.6	34.6	7.8
10 yrs	42	142.8	5.0	37.4	2.8
11 yrs	43	148.0	5.2	44.0	6.6
12 yrs	43	153.8	5.8	44.8	0.8
13 yrs	16	157.9	4.1	48.3	3.5
Mean			5.7		4.3
SD			1.7		2.9

Girls	n	Height	Diff.	Weight	Diff.
8 yrs	8	127.2		25.3	
9 yrs	32	135.8	8.6	33.0	7.7
10 yrs	56	143.3	7.5	38.9	5.9
11 yrs	46	149.0	5.7	43.2	4.3
12 yrs	56	155.8	6.8	49.6	6.4
13 yrs	9	159.9	4.1	52.5	2.9
Mean			6.5		5.4
SD			1.7		1.9

Somatic maturity group

Boys	n	Height	Diff.	Weight	Diff.
PHV -5	12	127.1		25.3	
PHV -4	23	134.6	7.5	31.0	5.7
PHV -3	62	141.7	7.1	36.7	5.7
PHV -2	55	149.5	7.8	43.3	6.6
PHV -1	36	158.1	8.6	50.7	7.4
PHV					
Mean			7.8		6.4
SD			0.6		0.8

Girls	n	Height	Diff.	Weight	Diff.
PHV -3	15	130.3		27.7	
PHV -2	39	138.2	7.9	33.4	5.7
PHV -1	64	145.4	7.2	40.6	7.2
PHV	47	151.6	6.2	45.6	5.0
PHV -1	36	160.2	8.6	54.3	8.7
Mean			7.5		6.7
SD			1.0		1.6

Diff, difference between corresponding age to the row and one-year younger age (e.g., 9 and 8 yrs).
PHV, peak height velocity.
Adapted from Sherar, Esliger, Baxter-Jones, & Tremblay (2007).

Skeletal maturity spans infancy, childhood, and adolescence into young adulthood, but sexual and somatic maturation is limited to the time of puberty and adolescence (Table 4), resulting in a wide range of CA categories within stages. This is especially apparent at the beginning and the end of definitive maturity stages. The age cutoff for determining groups is arbitrary, and some degree of error is associated with each method for assessing maturity status (Malina et al., 2004). Also, SA has not been used to determine maturity in youth sports classification. These logistical problems of maturity assessments do not reduce the utility of CA for a classification criterion. In addition, mean CAs and SAs at each stage of selected maturity indicators are quite close (Table 5) although variation in SA is generally less in both sexes (Marshall, 1974; Hauspie, Bielicki, & Koniarek, 1991).

It is concluded that the procedures for classifying youth athletes into maturity-based categories have severe limitations. Therefore, the sports federations have used CA and sex for classification systems for individual sports. Indeed, we must appreciate the fact that the utility of CA and sex as classification criteria is the only logistically practicable, achievable method in field settings.

Table 4. Commonly used indicators for assessing biological maturity.

Maturity indicators		Sex	Numbers of stages	Span	Classifier
CA		both		all age	
SA		both		infancy to young adulthood	assessor
SSCs	breast	W	5	puberty to adolescent	assessor/ self
	pubic hair	W	5 or 6	puberty to adolescent	assessor/ self
	menarche	W	> 3	puberty to adolescent	assessor/ self
	genital	M	5	puberty to adolescent	assessor/ self
	pubic hair	M	5 or 6	puberty to adolescent	assessor/ self
PHV		both	3	puberty to adolescent	assessor

CA, chronological age; SA, skeletal age; SSCs, secondary sex characteristics; W, woman; M, men; PHV, age at peak height velocity

Table 5. Relationships between chronological age (CA) and skeletal age (SA) at the time of reaching certain maturational events during adolescence.

Maturity	CA (yrs)		SA (yrs)	
Indicators	mean	SD	mean	SD
[Girls]				
B2	11.0	1.1	10.9	1.0
B5	14.0	0.9	14.0	0.8
PH3	12.5	1.0	12.5	0.8
PHV	12.3	1.1	12.5	0.9
M	13.2	0.8	13.3	0.4
95% adult Ht	12.8	0.8	13.0	0.3
[Boys]				
G2	11.5	1.1	11.5	1.2
G5	14.5	1.0	14.8	0.8
PH3	13.8	0.9	13.6	1.0
PHV	13.9	1.0	14.0	0.8
95% adult Ht	14.6	0.7	15.1	0.3

B, breast development stage; PH, pubic hair development stage
PHV, age at peak height velocity; M, age at menarche;
95% adult Ht, age at 95% of predicted adult height; G, genital developmental stage
Adapted from Marshall (1974). For complete definitions see pages 13-15.

Classification Systems in Swimming

Classifying youth swimmers for fair and appropriate competition is perplexing and remains unresolved. As outlined above, for practical reasons CA and sex are the only acceptable classification criteria in swimming. Federation Internationale de Natation Amateur (FINA) establishes rules for age-grouping in diving, water polo, and synchronized swimming. However, those in competitive swimming are described only as follows: "Federations may adopt their own age group rules, using FINA technical rules" (FINA, 2008). Thus each country and its swimming federation are permitted to establish their own age classification system for youth swimmers. The following are current age classification systems enforced by several representative swimming countries (Table 6).

k) Australia

Swimming Australia provides 5 age-groups, and the same groupings are utilized for girls and boys (unisex age-groups). They are the age of 13 years and under, 14, 15, 16, and 17-18 years. There seems to be no group established for swimmers aged 12 years and under, and consequently those swimmers are included in the youngest group.

Summary: 13 yrs & under, 14, 15, 16, and 17-18 yrs

l) Britain

British Swimming offers two age-group championships such as the National Youth Championship (NYC) and the National Age Group Championship (NAGC) for swimmers aged 11 to 18 years. NYC classifies participants into 14-15 and 16-17 year-old groups for women and 15-16 and 17-18 year-old groups for men, while the predetermined qualification time (QT) for the championships is provided for each CA. The NAGC does not combine CA categories into a group. Consequently, the meet has three age-groups (11-, 12-, and 13-year-old groups) for women swimmers and four age-groups (11-, 12-, 13-, and 14-year-old groups) for the men. Thus, five and six sex-specific age-groupings are offered for British swimmers.

On the other hand, there is the National County Team Championship. This competition classifies swimmers into 3 unisex age- groups: 12-13, 14-15, and 16-17 year-old groups. There seems to be no national meet for swimmers aged 10 years and younger.

Summary: Women, 11, 12, 13 yrs (NAGC) and 14-15, 16-17 yrs (NYC)

Men, 11, 12, 13, 14 yrs (NAGC) and 15-16, 17-18 yrs (NYC)

QT, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18 yrs

m) Canada

Sex-specific age-groupings are offered for the national swim meet by Swimming Canada. For women swimmers, age-groups of 12 years and under, 13, 14, 15, and 16-18 years are established. For the men, 13 years and under, 14, 15, 16, 17-18 years are provided. Women swimmers aged 11 years and under and men swimmers aged 12 years and under seem to compete in the youngest age-groups.

Summary: Women, 12 & under, 13, 14, 15, and 16-18 yrs

Men, 13 & under, 14, 15, 16, and 17-18 yrs

n) China

According to the results of the Chinese national age-group championships, there are five unisex age-groups for both sexes, 10, 11, 12, 13-14, and 15-17 year-old groups. The Chinese juvenile swimming tournament in 2005 adopted three age-groups (12 years & under, 13-14, and 15 years & over), whereas the same swim meet in 2006 utilized four age-groups for both sexes (age-groups of 11, 12, 13, 14-15, and 16-18 years). Thus, age-groupings are different among swim meets and even among years. However, age-grouping systems in China seem to be complicated and based on the program or project in relation to the Olympic Games prepared by the Chinese Swimming Association.

On the other hand, age-group classifications in Macau and Hong Kong belonging to China are different from the mainland. This is because these provinces have their own swimming association and each association establishes its own age-grouping system. In Macau, six unisex age-groups are provided:

8 years and under, 9-10, 11-12, 13-14, 15-17, and 18-24 years old groups. In Hong Kong, there are four unisex age-groups: age 10 years and under, 11-12, 13-14, and 15 years and over.

Summary: 10, 11, 12, 13-14, and 15-17 yrs (Chinese national age-group championships)

Age-grouping systems are different among provincial swimming associations.

10 & under, 11-12, 13-14, and 15 yrs & over (Hong Kong)

8 & under, 9-10, 11-12, 13-14, 15-17, and 18-24 yrs (Macau)

o) Germany

According to the results of swim meets organized by the German Swimming Federation, there are at least two different age-grouping systems. Both systems adopt sex-specific age-groupings, but differently classify CA categories into a group. The first system is used for international swim meet (ISM) held in Germany. It offers six groups to both women (age 10, 11-12, 13-14, 15-16 years, 17 years & over, and open) and men (age 10, 11-12, 13-14, 15-16, 17-18 years, 19 years & over, and open). In regional swim meets (RSM), participants are classified into the following age-groups: 11, 12, 13, 14, 15, and 16-17 years old (women) and 13, 14, 15, 16, 17, and 18-19 years old (men).

Summary: Women, 10, 11-12, 13-14, 15-16, 17 yrs & over, and open (ISM)

11, 12, 13, 14, 15, and 16-17 yrs (RSM)

Men, 10, 11-12, 13-14, 15-16, 17-18, 19 yrs & over, and open (ISM)

13, 14, 15, 16, 17, and 18-19 yrs (RSM)

p) Japan

The Japan Swimming Federation establishes four unisex age-groups, such as 10 & under, 11-12, 13-14, and 15-18 years age-groups. QTs for the national age-group championship (Junior Olympics) are settled by single CA category between 9 and 18 years old, a similar system to British Swimming. According to a committee of the federation (by personal communication), the system regarding QT which is offered by single CA category is an attempt to encourage and motivate young swimmers to continue to swim and also to be highly competitive (i.e., enlivenment and reinforcement of young swimmers). Many young swimmers seem to terminate their competitive swimming careers when they move up to older age-groups and competitive levels become higher. In addition, a high demand for academics and schoolwork accompanying an advancing age is another reason for the termination. The 15-18 years old group is intended to promote high school swimmers competing together.

There are also two national interscholastic swim meets; one is for middle school students combining 7th to 9th graders into a group, and another is for high school students grouping 10th to 12th graders. The state championship is the biggest meet for elementary school students offered for 1st -6th graders.

Summary: 10 & under, 11-12, 13-14, and 15-18 yrs (Junior Olympics) with single-age-based QTs (9, 10, 11, 12, 13, 14, 15, 16, 17, and 18 yrs)

6th and under, 7-9th, and 10-12th grades (interscholastic swim championships)

q) New Zealand

Swimming New Zealand provides unisex three age-groups for Junior Championships which classifies participants into age 10 and under, 11, and 12 years groups. Also, in Age Group Championship, 13 to 18 year-old swimmers are classified into five age groups, such as 13, 14, 15, 16, and 17-18 years. Thus, the number of age-groups enforced by Swimming New Zealand is the greatest among investigated countries for the present study.

Summary: 10 & under, 11, 12, 13, 14, 15, 16, and 17-18 yrs

r) Spain

Real Federación Española de Natación defines a common nominal age category applied to all competitive youth sports in Spain, and six sex-specific age categories are provided. The youngest age group, BENJAMIN, includes 10-11 years old boys and 9-10 years old girls. The second youngest group is ALEVIN, combining 12-13 years old boys and 11-12 years old girls. Fourteen to sixteen years old boys and 13-14 years old girls belong to INFANTIL. Seventeen and eighteen year-old men and 15-16 year-old women are categorized into JUNIOR, and 19-20 year-old men and 17-18 year-old women are in

ABSOLUTO JOVEN. The last category, ABSOLUTO is for the age of 21 years and over for men and 19 and over for women.

Summary: Women, 9-10, 11-12, 13-14, 15-16, 17-18, and 19 yrs & over

Men, 10-11, 12-13, 14-16, 17-18, 19-20, and 21 yrs & over

s) Taiwan (Chinese Taipei)

Chinese Taipei Swimming Association offers two national age-group championships in Taiwan. The first is the national age-group championship which partitions swimmers into the same four unisex age-groups as Hong Kong: ages of 10 years & under, 11-12, 13-14, and 15 years & over. The second is the national youth championship, an interscholastic swim meet. The groups are based on school grades, and there are five unisex groups: 1^{st}-2^{nd}, 3^{rd}-4^{th}, 5^{th}-6^{th} (elementary school students), 7^{th}-9^{th} (middle school students) and 10^{th}-12^{th} (high school students) grades. The age-group rules in Taiwan are based on Asian Amateur Swimming Federation (AASF) whose administrative headquarter is in Japan.

Summary: 10 & under, 11-12, 13-14, and 15 yrs & over (national age group championship)

1-2, 3-4, 5-6, 7-9, and 10-12^{th} grades (interscholastic swim meet)

t) The United States

Age-groups and the QT for championship competition are established by each local swimming committee (LSC) belonging to USA Swimming. For instance, South and Central California Swimming seem to offer a group and QT for age 8 years and under swimmers for Junior Olympics. According to the most recent rules and regulations (USA Swimming, 2008), there are typically four unisex age-groups in the U.S. First, age 14 years and younger swimmers (age-group swimmers) are classified into four age-groups: age 10 years and under, 11-12, and 13-14 years groups for the age group state championship. Next, age 15 years and over swimmers are categorized as a senior group as well as open. Senior state championships are offered for all members of USA Swimming with a QT, and even 14 year-old and under swimmers can participate in the senior championships if they achieve the QT.

The age-grouping rules of swimming in the U.S. have been modified to allow for some flexibility and creativity by the Amateur Athletic Union since 1947 and USA Swimming since 1978 (Bauer, 1967; personal communication with USA Swimming). Local swim meets can be conducted with single age groups, i.e. 8, 9, 10, 11, 12, 13, and 14 years old. They can also be conducted with non-traditional groups such as 10-11, 12-13, and 14-15 years old group. Age 15 years and over swimmers are usually classified into an 'open' or '15 and over' group in local swim meets. There also seem to be swim meets with all age-groups combined, but swimmers are seeded by time and awarded separately based on traditional age-groupings. All meet formats for local meets are always arranged and modified by the host swim teams to make the meet interesting and exciting.

Summary: 10 & under, 11-12, 13-14, and 15 yrs & over (championships)

Age-grouping systems are different among LSCs as well as swim meets.

Table 6. Age-group classification in representative swimming countries (federations).

<table>
<tr><th>Country</th><th>Sex</th><th>< 8 yrs</th><th>9 yrs</th><th>10 yrs</th><th>11 yrs</th><th>12 yrs</th><th>13 yrs</th><th>14 yrs</th><th>15 yrs</th><th>16 yrs</th><th>17 yrs</th><th>18 yrs</th><th>19 yrs <</th><th>20 yrs</th><th>Σ</th></tr>
<tr><td>Australia</td><td>unisex</td><td colspan="6">◆</td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td></td><td></td><td>5</td></tr>
<tr><td rowspan="3">Britain</td><td>Girls</td><td></td><td></td><td></td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td></td><td></td><td></td><td>5</td></tr>
<tr><td>Boys</td><td></td><td></td><td></td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td></td><td></td><td>6</td></tr>
<tr><td>QT</td><td></td><td></td><td></td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td></td><td></td><td>8</td></tr>
<tr><td rowspan="2">Canada</td><td>Girls</td><td colspan="5">◆</td><td>◆</td><td>◆</td><td>◆</td><td colspan="3">◆</td><td></td><td></td><td>5</td></tr>
<tr><td>Boys</td><td colspan="6">◆</td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td></td><td></td><td>5</td></tr>
<tr><td>China*</td><td>unisex</td><td></td><td></td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td colspan="3">◆</td><td></td><td></td><td></td><td>5</td></tr>
<tr><td>Hong Kong</td><td>unisex</td><td colspan="3">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="4">◆</td><td></td><td></td><td>4</td></tr>
<tr><td>Macau</td><td>unisex</td><td>◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="3">◆</td><td colspan="2">◆</td><td></td><td>6</td></tr>
<tr><td rowspan="2">Germany</td><td>Girls</td><td></td><td></td><td></td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td></td><td></td><td></td><td>6</td></tr>
<tr><td>Boys</td><td></td><td></td><td></td><td></td><td></td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td></td><td>6</td></tr>
<tr><td rowspan="2">Japan</td><td>unisex</td><td colspan="3">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="4">◆</td><td></td><td></td><td>4</td></tr>
<tr><td>QT</td><td></td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td></td><td></td><td>10</td></tr>
<tr><td>New Zealand</td><td>unisex</td><td colspan="3">◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td>◆</td><td colspan="2">◆</td><td></td><td></td><td>8</td></tr>
<tr><td rowspan="2">Spain</td><td>Girls</td><td></td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td>◆</td><td></td><td>6</td></tr>
<tr><td>Boys</td><td></td><td></td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="3">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td>5</td></tr>
<tr><td>Taiwan</td><td>unisex</td><td colspan="3">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="5">◆</td><td></td><td>4</td></tr>
<tr><td>USA*</td><td>unisex</td><td colspan="3">◆</td><td colspan="2">◆</td><td colspan="2">◆</td><td colspan="5">◆</td><td></td><td>4</td></tr>
</table>

Unisex = the same age-groupings are adopted for girls and boys; QT, qualification time for national or state youth (age-group) championships; < 8 yrs, 8 years and under 19 yrs <, 19 years and over; Σ, the total number of age-groups

*Age-grouping systems are different among local swimming committees or provincial swimming associations.

Data were derived from the website of each federation.

Preliminary Results

Issues Regarding Age-Groupings Adopted by USA Swimming

A wide variety of age-grouping systems in swimming are currently used throughout the world. Some countries appear to be considering fairness and equity in competition when designating competitive groupings, while many countries seem to fail to take into account the developmental characteristics of adolescent swimmers. The use of single CA categories for youth swimmers, especially in the transition into and during puberty, appears important due to variability of maturation status within a given CA. This supposition is supported by Malina & Beunen (1996) suggesting the use of narrower CA groups. Age-group championships are typically held twice a year. Consequently, if a swimmer could compete in a single CA category, there would be more chances to succeed or experience being competent, thereby encouraging the swimmer to continue to swim and to be ultimately competitive. However, when swimmers are in the growth spurt period, theoretically between age 9 and 15 years in girls and age 11 and 17 years in boys (Malina et al., 2004; Roemmich & Rogol, 1995) and they are combined into a group, it is easy to suspect that there might be maturity-based performance outcomes within the group.

In addition, a need for sex-specific age-grouping systems is proposed in connection with sex-differences in timing of growth spurt and maturity, provided that combining plural CA categories into a group is necessary due to logistic reasons (meet timelines or expenses). Previous data have revealed that average girls enter into the adolescent growth spurt and reach maturity sooner than boys (Marshall & Tanner, 1986). This concept may also be supported by previous findings demonstrating little or no difference in maturity-associated variation or improvement in motor performance between girls, but boys revealed maturity-associated differences in motor performance (Jones, 1949; Lefevre et al., 1988; Little, Day, & Steinke, 1997; Malina et al., 2004). Furthermore, it is proposed that prepubertal girls and boys may be able to compete together because of small biological differences and trainability among prebubertal children resulting from the lack of hormonal control (Katch, 1983). Consequently, if grouping swimmers of different CAs is necessary, prepubertal swimmers might be classified together. This idea may encourage swimmers in the 8 and under age-group, which usually consists of a smaller number of participants in a swim meet. However, there is no literature demonstrating the rationale for supporting these proposals, nor is there only rationale behind the current age classification in swimming.

From this discussion, age-grouping systems adopted by USA Swimming may be contradictory to the purpose and intent of providing fair and equalized competition. Swimmers are stratified by more than two CA categories (10 & under, 11-12, 13-14, and 15 & over), and the same age-groupings are applied to both sexes. In the view of fair competition for biologically diverse adolescent swimmers, USA Swimming needs to take the current age-groupings into more careful consideration. Swimmers in the U.S. may be competing in a situation where performance outcomes can be considerably influenced by maturity giving some swimmers an advantage over others. For example, according to the results of Indiana Age-group State Championships (March, 2008; http://www.inswimming.org) for swimmers age 14 years and under, maturity-influenced performance outcomes seem to be demonstrated. Figure 1 A-D show the percentage of swimmers by age in the top 16 and total participants within each age-group. The older swimmers within an age-group (age 10, 12, and 14 years) clearly prevail over younger competitors (age 9 & under, 11, and 13 years). The markedly different percentages within age-groups are seen in both the top 16 (A and C) and total participants (B and D). The qualification times for participation in this meet were based on the time of the 32th swimmer at the previous championships. Figure 1 B and D illustrate that very few swimmers not at the “top of the age-group” are able to qualify. Therefore, the customary age-grouping is disadvantageous for the younger swimmers within an age-group.

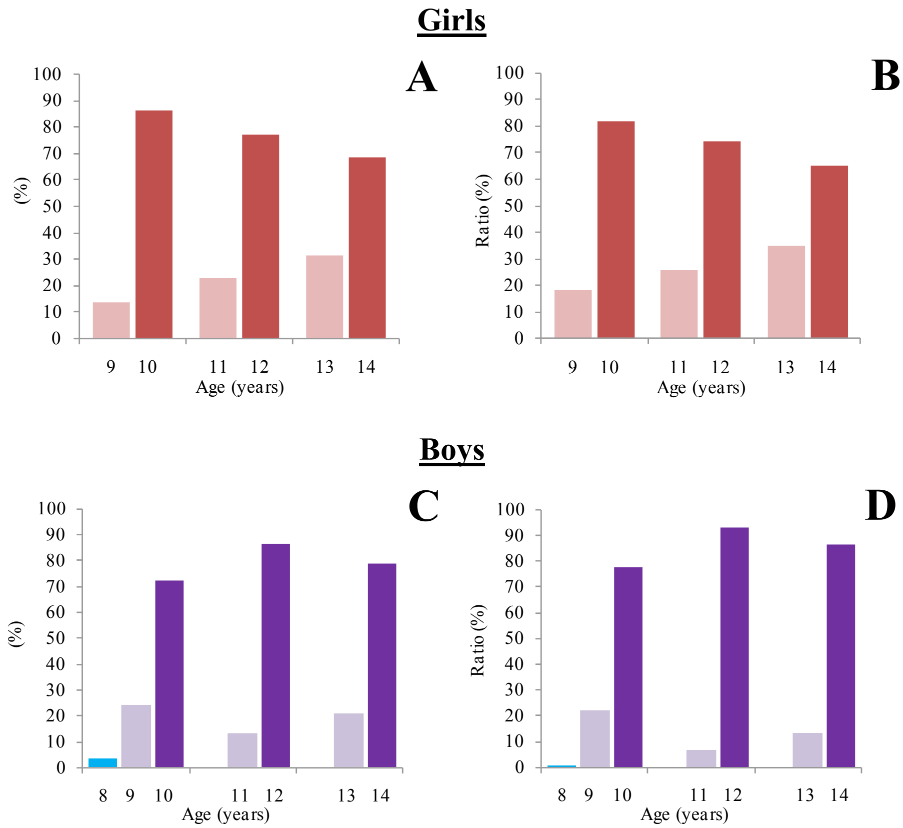

Figure 1 A-D. The percentage of girl (A & B) and boy (C & D) swimmers in each CA category at the Indiana Age-group Championships (2008, March). A & C, top 16 swimmers; B & D, total participants

Lastly, the current age-grouping appears to influence the retention of USA Swimming memberships. Table 7 presents the renewal rate of year-around athlete memberships in 2007, modified from the data of USA Swimming (2008). The cutoff line for age-groups is drawn by a heavy line, and younger groups within age-groups are highlighted. A significant difference ($p < 0.01$) in the renewal rate was found between younger (mean 71.1 ± 0.7 %; 11, 13, and 15 years old) and older (mean 73.4 ± 1.7 %; 10, 12, 14, and 16 years old) swimmers within age-groups. This illustrates that there is a trend for younger swimmers within age-groups (who were in older swimmers within the age-groups in the previous year) to halt their competitive swimming careers as they move up age-groups, while older swimmers within age-groups, who were in younger groups in the preceding year, tend to retain their swimming membership. Thus, there is evidence that the customary age-groups enforced by USA Swimming need to be reconsidered in connection with equity and fairness in competition. Major issues related to the age-grouping system include; where the line should be drawn between CA categories; and whether there is a better way to assure fair competition in swimming.

Table 7. Renewal rate of year-around athlete memberships of USA Swimming in 2007.

Renew rate for 2007 (%)				Number of dropouts after 2006 season
Age (years)	Women	Men	Total	
10	72.5	70.9	71.9	5946
11	72.1	70.9	71.6	7405
12	73.3	70.2	72.1	7957
13	71.9	70.3	71.3	8180
14	75.7	75.3	75.5	6338
15	70.0	70.9	70.3	7042
16	72.7	76.2	74.0	5072
17	72.9	79.9	75.8	4221
18	65.3	73.8	69.1	4355
19	73.0	96.4	84.0	1589
Mean	71.9	75.5	73.6	-

Shaded rows represent younger swimmers in each age-group.
Adapted from reports of USA Swimming (2008)

History of Age-Group Swimming in the U.S.

Age-group swimming in the U.S. germinated in 1947 by Carl Bauer, the father of age-group swimming, at the Missouri Athletic Club in St. Louis (Colwin, 1998; International Swimming Hall of Fame [ISHF], 1967a). He devised the system of swimming competitions graduated by age from 8 to 18 years. Subsequently, the system was adopted and further developed by Beth Kaufman in California, causing a great upsurge in swimming, particularly in California. The age-grouping concept soon spread worldwide, encouraging thousands of children to take up competitive swimming. Around the time when the age-grouping system was created, a difficulty lay in overcoming many outmoded practices (ISHF, 1967b). For instance, only a few aquatic stars and champions were developed to their fullest, while many potential stars did not get a chance to gain national recognition due to the selectivity of the monopolists. The guidance of the nation's foremost swimmers and divers was handled by specialty coaches and managers. However, from the time Carl Bauer conceived the idea of age classification, age-group swimming has grown faster than anyone could have imagined. It solved the problem of development opportunities for youngsters and provided a selection system for national swimmers (ISHF, 1967a). It is accepted that the advent of formal age-group swimming was one of the most important developments of swimming in the 20th century.

However, there has been no analytical rationale for the age-grouping system adopted by USA Swimming, in spite of the positive outcomes of the program. No clarification or explanation regarding how the age-groupings have been created has been documented. With the controversy over the current age-grouping system for swimmers and the lack of scientific rationale behind the age-groupings, an in depth analysis of grouping swimmers based on CA is necessary. This effort could result in reconsideration of the current age-groupings and support mass opinion concerning age classification based on single CA.

Summary

The efficacy of the classification systems utilized in youth sports competition has engaged sport-governing bodies and youth sport organizations in extensive worldwide debate for some time. Because considerable differences in the rate and timing of maturation among children disqualify CA as an accurate index of physical potential, the use of maturity-based assessments for classifying youth sports participants have been frequently recommended in the literature. However, doing so is not logistically possible due to the obvious complexity in theory and in actual practice of maturity assessments. Even if maturity-based classifications could be employed, they may not necessarily ensure fair competition because of variation within and between the different maturity indicators. Allowing for the ease of using CA categories as classification criteria, age-group classification currently is the only acceptable, practicable system in swimming. The major tasks facing CA-based grouping systems are where the line should be drawn between CA categories and whether there is a better way to ensure fair competition.

The following are key synopses of the review of literature.

- Matching youth sports participants in order to make competition fair and safe is an important goal of sports federations.
- Chronological age is the only operable approach for classifying youth athletes in the field setting.
- USA Swimming has established four unisex age-groups based on CA: 10 years & under, 11-12 years, 13-14 years, and 15 years & over.
- Due to considerable differences in growth and maturational status among adolescents within any given CA, combining swimmers of different ages into a group may not ensure fair competition.
- Because younger aged or late maturing swimmers within an age-group are physically behind their same age-group older or precocious peers, the current age-grouping system may discourage them from continuing competitive swimming.
- There is no historical or documental rationale for the current USA Swimming age-grouping system.

Chapter 3

METHODOLOGY

The problem of this study was to ascertain the adequacy of the current age-group classification enforced by USA Swimming by evaluating and comparing swim performance across ages as well as within age-groups. There has been a lack of rationale supporting the competitive age-groups in the U.S.; therefore this study was conducted to evaluate age-group classification and to provide an analytical rationale in support of the current or alternative age-groups.

The implementation of the study included the following organizational steps: (a) arrangements for conducting the study; (b) selection of variables and gathering data; (c) data analysis.

Arrangements for Conducting the Study

The study was conducted under approval received from Indiana University Human Subject Committee (Appendix A).

Selection of Variables and Gathering Data

All data were acquired through the websites of USA Swimming (http://www.usaswimming.org) and Indiana Swimming (http://www.inswimming.org). The main variables to test the hypotheses included: (a) swim times of the top 100 U.S. women and men for each year (2005-2007), (b) seven events (50-, 100-, and 200-yard freestyle, 100-yard backstroke, butterfly, and breaststroke, and 200-yard individual medley), (c) sixteen age categories from 5 to 20 years old as well as an age-group of 21 years and over, resulting in a total of 17 separate competitive age-groups for each sex.

These variables were selected to provide the study with the external factor that would allow the results to be generalized to populations in competitive age-group swimming in the U.S. A group of age

21 years and over (21&O) was included in the sample to represent "the national level." The seven events were selected because they are employed in all age-groups as official competitive swimming events. To evaluate the competitive age-groups, swim times of the top 100 U.S. women and men from the past seven years (2000-2007) were selected to analyze. Any year lacking times of the top 100 women and men swimmers for each CA category and for 7 events (an incomplete data set) was excluded from data collection in this study. In addition to deficient and incomplete data, any years with unrealistic swim times and errors in the database were not used (years 2000 to 2002). Although the complete number of data for all age-groups and events required for the study were obtainable from the databases of 2003 and 2004, the average swim times were significantly slower as compared to those of 2005, 2006, and 2007 (Table 8 and Figure 2 A-B). There was no significant difference in swim times among 2005, 2006, and 2007 (Table 9 and Figure 3 A-B). As a result, the data from those three years (2005-2007) were pooled and averaged for each sex, each CA category, and 7 separate events. This average represented the overall swimming population in the U.S.

Table 8. The average time of the top 100 U.S. swimmers for 16 age categories* in 100-yard freestyle from 2003 to 2007.

	Women		Men	
Year	Time (sec)	N	Time (sec)	N
2003	60.51 ± 14.8	1600	57.72 ± 16.9	1600
2004	59.72 ± 13.0 ‡	1600	56.76 ± 14.7 ‡	1600
2005	59.45 ± 12.7 ‡†	1600	56.48 ± 14.5 ‡†	1600
2006	59.35 ± 12.7 ‡†	1600	56.44 ± 14.7 ‡†	1600
2007	59.28 ± 12.9 ‡†	1600	56.27 ± 14.6 ‡†	1600

* 16 categories consist of ages 6 to 20 years and an age-group of 21 years and over.
‡ Significant difference from 2003 ($p < 0.01$)
† Significant difference from 2004 ($p < 0.01$)

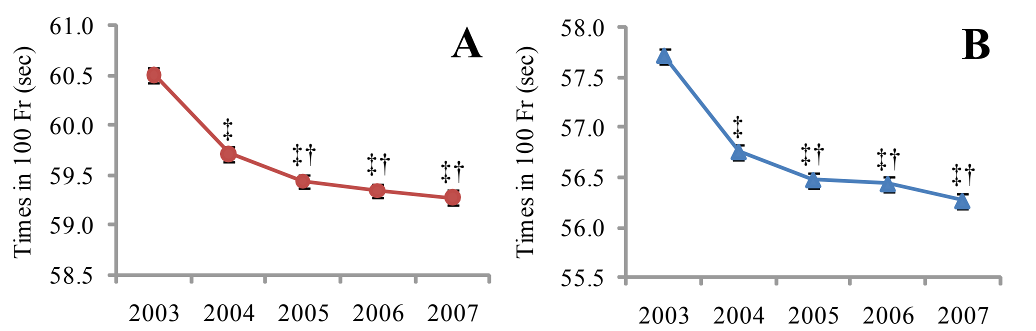

Figure 2 A and B. Comparison of the average time (± S.E.) in 100-yard freestyle among the past five years in women (A) and men (B) swimmers in the U.S.
Each plot represents the average time of 1600 swimmers consisting of top 100 swimmers for 16 categories (ages 6 to 20 years and a group of 21 years and over).
‡ Significant difference from 2003 ($p < 0.01$); † Significant difference from 2004 ($p < 0.01$).

Table 9. Year-differences (2005, 2006, and 2007) in the average swim time of the top 100 U.S. women and men swimmers (ages 6 to 20 years and a group of 21 years and over) for seven swim events.

Women

Events		year 2005		year 2006		year 2007		
STKs	Dist.	Time (sec)	N	Time (sec)	N	Time (sec)	N	Sig. (p)
Fr	50	28.54 ± 7.9	1700	28.48 ± 7.8	1700	28.44 ± 7.9	1700	0.927
Fr	100	59.45 ± 12.7	1600	59.35 ± 12.7	1600	59.28 ± 12.9	1600	0.938
Fr	200	124.65 ± 22.6	1500	124.24 ± 21.8	1500	123.50 ± 21.1	1500	0.348
Ba	100	64.71 ± 11.9	1500	64.47 ± 11.6	1500	64.00 ± 11.3	1500	0.233
Br	100	73.26 ± 13.5	1500	73.14 ± 13.3	1500	73.00 ± 13.3	1500	0.868
Fly	100	62.04 ± 9.4	1400	61.85 ± 9.0	1400	61.45 ± 8.8	1400	0.217
IM	200	141.28 ± 26.6	1400	140.56 ± 25.3	1400	139.94 ± 24.7	1400	0.356

Men

Events		year 2005		year 2006		year 2007		
STKs	Dist.	Time (sec)	N	Time (sec)	N	Time (sec)	N	Sig. (p)
Fr	50	27.24 ± 9.1	1700	27.19 ± 9.1	1700	27.11 ± 9.1	1700	0.919
Fr	100	56.48 ± 14.5	1600	56.44 ± 14.7	1600	56.27 ± 14.6	1600	0.912
Fr	200	118.32 ± 25.2	1500	118.28 ± 25.5	1500	118.01 ± 25.6	1500	0.934
Ba	100	61.31 ± 13.8	1500	61.15 ± 13.8	1500	60.81 ± 13.7	1500	0.597
Br	100	69.73 ± 16.3	1500	69.67 ± 16.5	1500	69.34 ± 16.4	1500	0.784
Fly	100	58.17 ± 11.0	1400	58.05 ± 11.1	1400	57.84 ± 10.9	1400	0.722
IM	200	133.72 ± 30.3	1400	133.22 ± 29.8	1400	133.09 ± 30.7	1400	0.836

STKs, strokes; Dist., distance (yards); Sig., significance; Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley

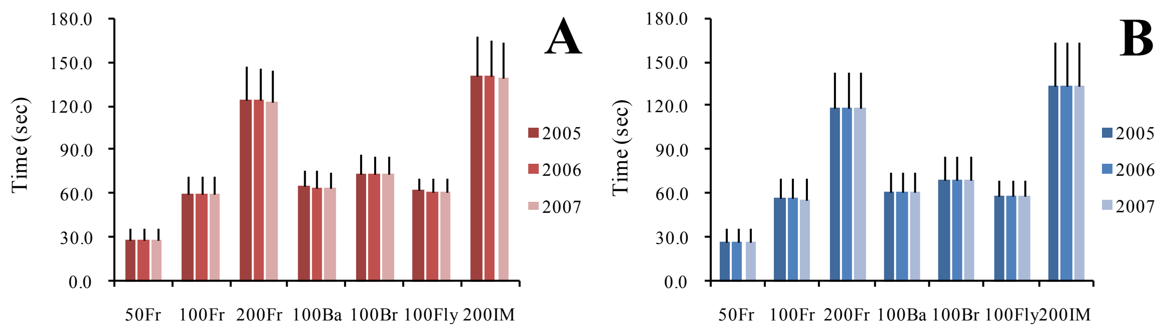

Figure 3 A and B. Year-differences (2005, 2006, and 2007) in the average swim time of the top 100 U.S. women and men swimmers (ages 6 to 20 years and a group of 21 years and over) for seven events. A, women; B, men; Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley There is no significant difference among years (2005-2007) for any swim event.

For data collection there was a deficiency of data in younger age categories, 5-, 6- and 7-year-old, in some events. The data of the top 100 swimmers in the 5-year-old category were available for only 50 yards freestyle (Fr), while complete data in 6-year and older age-groups were obtainable in 50- and 100-yard Fr only. The data for the 200-yard Fr as well as the 100-yard backstroke (Ba) and breaststroke (Br) were accessible for 7-year-old and over. In other stroke events (butterfly, Fly; individual medley, IM), 8-year and older categories were used in the study. Table 10 shows the age range and sample size used in the study. For example, the sample size (N) for the women's 50-yard Fr is described as follows: 17 age-groups (5-20 + 21&O) × 100 swimmers × 3 years (2005 - 2007) equals 5100. Finally, outcomes of the current paradigm were compared to novel theoretical groupings to propose alternative age-groups.

Table 10. Age-groups and sample size used in the study.

STKs	Dist.	Women	N	Men	N
Fr	50	5 yrs & over	5100	5 yrs & over	5100
Fr	100	6 yrs & over	4800	6 yrs & over	4800
Fr	200	7 yrs & over	4500	7 yrs & over	4500
Ba	100	7 yrs & over	4500	7 yrs & over	4500
Br	100	7 yrs & over	4500	7 yrs & over	4500
Fly	100	8 yrs & over	4200	8 yrs & over	4200
IM	200	8 yrs & over	4200	8 yrs & over	4200

STKs, strokes; Dist., distance (yards); Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley

Data Analysis

Descriptive statistics (mean ± standard deviation) were utilized to characterize the performance levels of each age-group. Univariate analysis of variance (ANOVA) with Tukey's post-hoc test was used for the comparison of swim times among the 5 years. A 17 × 2 × 7 (age × sex × event) ANOVA with Tukey's post-hoc test was performed to test the hypotheses. If the F-ratio for any of the interactions was significant, simple main effect (or simple-simple main effect) using a one-way ANOVA was performed to assess whether or not different levels of significance existed. If there was significance, Tukey's post-hoc test was used to determine where the significant differences were, in an attempt to identify significant age-, sex-, and event-differences. In addition to testing differences in swim time, alternative age-groups were proposed by referring to homogeneous subsets (Tukey range test) which list all the groups (the categories on the independent variable) and their means where the group means do not differ significantly. The level of significance was set at P value of less than 0.01. All calculations and analyses were performed using the Statistical Package for the Social Sciences (SPSS 16.0 for Windows; SPSS Inc., Chicago, IL).

Chapter 4

ANALYSIS AND DISCUSSION OF DATA

Considerable differences in maturity status among swimmers within age-groups result in size and strength differences and cause maturity-based performance outcomes in competition. The current age-grouping system enforced by USA Swimming does not seem to function as a means of equalizing competition and minimizing the influence of maturity differences. The focus of the study was on determining whether or not there is evidence of a better way to ensure fair competition for age-group swimmers in the U.S., based on an analysis of swim performance of the top 100 women and men by ages 5 to over 21 years old. The purposes of the study were to evaluate the age-groups and to determine whether or not a statistical rationale exists for the current age-groups or for the alternatives.

Six hypotheses questioning the adequacy of the current age-grouping systems were tested. The hypotheses are:

H_1: There is a significant difference in swim performance among CAs.

H_2: The differences in swim time between adjacent ages become smaller with the increase in CA.

H_3: There is a significant difference in swim performance within the current age-groups.

H_4: The difference in swim performance between CAs within age-groups can be reduced.

H_5: Age-groupings in women swimmers are different from those in the men.

H_6: There is no significant sex-related difference of swim performance in 8 yrs & younger age-categories.

The analysis of the data is presented in this chapter according to the following topics: (a) Age-Related Differences in Swim Performance; (b) Sex-Differences in Swim Performance; (c) Alternative Age-Groupings; and (d) Discussion of Findings.

Age-Related Difference in Swim Performance

The results of age-related difference of swim performance in women and men for all events are presented in Tables 11 and 12, respectively.

Women

Table 11 presents the mean times of the top 100 U.S. women swimmers for 15 age categories in all seven events. There were significant differences in swim time between each CA up to 15 years old for all events ($p < 0.01$) with the exception of 200-yard IM ($p = 0.02$ between ages of 14 and 15). In freestyle events, the significant age-related differences for 50, 100, and 200 yards were demonstrated up to 16, 15, and 15 year-old groups, respectively. All 100-yard stroke events (Ba, Br, and Fly) demonstrated a similar pattern of significant age-differences in swim performance to 100 and 200 yards Fr, that is, up to 15 years old. The swim times of the 21&O group were significantly faster than all other age categories ($p < 0.01$) in all events with the exception of 200-yard events. In 200 yards Fr, no significant difference was found among 19-year, 20-year, and 21&O age-groups ($p = 0.03$). There was no significant difference between 18-year and 21&O age-groups in the 200 IM ($p = 0.05$).

Men

Table 12 presents the mean times of the top 100 U.S. men swimmers for 15 age categories in all seven events. Significant age-related differences in swim time were found up to 17 years old for all events in men, excluding 50-yard Fr and 200-yard IM ($p = 0.12$ between ages of 16 and 17). In freestyle events, there were significant differences among all CA categories in 50-yard Fr and between each CA up to 17 year-old categories in both 100 and 200-yard Fr. Like women swimmers, all 100-yard stroke events demonstrated a similar pattern regarding significant age-differences in performance across ages to 100 and 200 yards Fr. The swim times of the 21&O group in men were significantly faster than all other age categories in all seven events.

Table 11. The average times of the top 100 U.S. women swimmers for 15 age categories in 7 events (mean ± S.D).

STKs	Dist.	7 yrs old	8 yrs old	9 yrs old	10 yrs old	11 yrs old	12 yrs old	13 yrs old	14 yrs old	15 yrs old	16 yrs old	17 yrs old	18 yrs old	19 yrs old	20 yrs old	21-yr & O
Fr	50	35.39 ± 1.3	31.99 ± 0.9 ‡	29.50 ± 0.7 ‡	27.54 ± 0.5 ‡	26.30 ± 0.4 ‡	25.28 ± 0.4 ‡	24.74 ± 0.3 ‡	24.28 ± 0.3 ‡	23.99 ± 0.3 ‡	23.77 ± 0.3 ‡	23.73 ± 0.3	23.65 ± 0.4	23.51 ± 0.5	23.45 ± 0.5	23.22 ± 0.5 ‡
Fr	100	80.59 ± 3.5	71.31 ± 2.4 ‡	65.06 ± 1.6 ‡	60.07 ± 1.0 ‡	57.24 ± 1.0 ‡	54.79 ± 0.8 ‡	53.59 ± 0.7 ‡	52.54 ± 0.6 ‡	51.92 ± 0.7 ‡	51.54 ± 0.6	51.39 ± 0.6	51.22 ± 0.9	51.07 ± 1.0	51.01 ± 1.0	50.43 ± 0.9 ‡
Fr	200	186.51 ± 10.7	158.15 ± 6.4 ‡	141.84 ± 3.7 ‡	130.99 ± 2.3 ‡	124.27 ± 2.1 ‡	118.45 ± 1.7 ‡	115.36 ± 1.5 ‡	113.04 ± 1.5 ‡	111.78 ± 1.5 ‡	111.04 ± 1.5	110.53 ± 1.4	110.45 ± 1.7	110.05 ± 2.0	110.27 ± 2.0	109.20 ± 2.1
Ba	100	96.71 ± 5.2	82.85 ± 3.1 ‡	74.52 ± 2.0 ‡	68.68 ± 1.4 ‡	64.76 ± 1.3 ‡	61.35 ± 1.1 ‡	59.60 ± 1.1 ‡	58.34 ± 1.0 ‡	57.66 ± 1.0 ‡	57.21 ± 0.9	57.03 ± 0.9	57.07 ± 1.2	56.99 ± 1.5	57.11 ± 1.6	56.00 ± 1.5 ‡
Br	100	110.45 ± 5.4	95.00 ± 3.3 ‡	84.45 ± 2.4 ‡	77.62 ± 1.7 ‡	72.99 ± 1.6 ‡	69.54 ± 1.5 ‡	67.50 ± 1.2 ‡	66.08 ± 1.1 ‡	65.43 ± 1.3 ‡	64.98 ± 1.3	64.81 ± 1.2	64.53 ± 1.4	64.79 ± 1.7	65.03 ± 1.8	63.75 ± 1.6 ‡
Fly	100		86.91 ± 5.0	74.98 ± 2.6 ‡	68.30 ± 1.8 ‡	64.09 ± 1.4 ‡	60.72 ± 1.1 ‡	58.94 ± 1.0 ‡	57.72 ± 0.9 ‡	57.03 ± 0.9 ‡	56.46 ± 0.9	56.13 ± 0.9	56.25 ± 1.2	56.23 ± 1.3	56.16 ± 1.4	54.98 ± 1.3 ‡
IM	200		179.34 ± 6.4	160.76 ± 4.3 ‡	148.52 ± 2.8 ‡	140.57 ± 2.7 ‡	134.09 ± 2.2 ‡	130.59 ± 2.2 ‡	127.75 ± 2.0 ‡	126.22 ± 2.2	125.35 ± 2.1	124.91 ± 2.1	124.37 ± 2.3	124.66 ± 2.7	124.75 ± 2.7	122.99 ± 2.4 ‡

‡ Significant difference from 1-year younger age category ($p < 0.01$)

Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley; STKs, strokes; Dist, distance (yards)

Table 12. The average times of the top 100 U.S. men swimmers for 15 age categories in 7 events (mean ± S.D).

STKs	Dist.	7 yrs old	8 yrs old	9 yrs old	10 yrs old	11 yrs old	12 yrs old	13 yrs old	14 yrs old	15 yrs old	16 yrs old	17 yrs old	18 yrs old	19 yrs old	20 yrs old	21-yr & O
Fr	50	35.14 ± 1.1	31.55 ± 0.9 ‡	29.20 ± 0.6 ‡	27.42 ± 0.5 ‡	25.99 ± 0.6 ‡	24.33 ± 0.5 ‡	23.32 ± 0.4 ‡	22.41 ± 0.3 ‡	21.95 ± 0.3 ‡	21.49 ± 0.3 ‡	21.13 ± 0.3 ‡	20.95 ± 0.3 ‡	20.75 ± 0.4 ‡	20.52 ± 0.4 ‡	20.04 ± 0.4 ‡
Fr	100	80.30 ± 3.3	70.25 ± 2.1 ‡	64.41 ± 1.6 ‡	59.89 ± 1.2 ‡	56.78 ± 1.2 ‡	53.13 ± 1.0 ‡	50.72 ± 0.8 ‡	48.81 ± 0.7 ‡	47.80 ± 0.7 ‡	46.89 ± 0.6 ‡	46.20 ± 0.5 ‡	45.85 ± 0.7	45.51 ± 0.9	45.02 ± 0.9 ‡	44.10 ± 0.8 ‡
Fr	200	188.32 ± 12.4	156.15 ± 6.4 ‡	139.62 ± 3.6 ‡	130.16 ± 2.5 ‡	123.28 ± 2.6 ‡	115.95 ± 2.0 ‡	110.45 ± 1.9 ‡	106.00 ± 1.6 ‡	103.81 ± 1.3 ‡	102.02 ± 1.3 ‡	100.74 ± 1.3 ‡	100.19 ± 1.5	99.83 ± 1.8	99.13 ± 1.9	97.41 ± 1.8 ‡
Ba	100	97.78 ± 5.5	81.87 ± 3.1 ‡	73.80 ± 2.2 ‡	68.41 ± 1.5 ‡	64.51 ± 1.6 ‡	60.23 ± 1.4 ‡	57.12 ± 1.1 ‡	54.55 ± 1.0 ‡	53.16 ± 1.0 ‡	52.20 ± 1.0 ‡	51.38 ± 1.0 ‡	51.13 ± 1.1	50.63 ± 1.4 ‡	50.38 ± 1.7	49.14 ± 1.3 ‡
Br	100	113.04 ± 6.8	95.13 ± 3.5 ‡	84.62 ± 2.5 ‡	78.35 ± 2.1 ‡	73.53 ± 1.9 ‡	67.97 ± 1.6 ‡	64.45 ± 1.4 ‡	61.67 ± 1.2 ‡	60.19 ± 1.1 ‡	59.23 ± 1.3 ‡	58.15 ± 0.9 ‡	57.71 ± 1.2	57.57 ± 1.6	56.89 ± 1.5 ‡	55.23 ± 1.3 ‡
Fly	100		86.27 ± 5.5	73.97 ± 2.7 ‡	67.70 ± 1.7 ‡	63.71 ± 1.7 ‡	59.25 ± 1.3 ‡	56.32 ± 1.1 ‡	53.75 ± 0.9 ‡	52.36 ± 0.8 ‡	51.17 ± 0.8 ‡	50.43 ± 0.8 ‡	50.02 ± 1.0	49.73 ± 1.1	49.35 ± 1.2	48.19 ± 1.0 ‡
IM	200		177.23 ± 6.8	158.80 ± 4.2 ‡	147.85 ± 3.0 ‡	139.90 ± 3.1 ‡	131.00 ± 2.9 ‡	124.66 ± 2.3 ‡	119.60 ± 1.8 ‡	116.80 ± 1.8 ‡	114.78 ± 1.6 ‡	113.19 ± 1.7	112.56 ± 2.1	111.88 ± 2.5	111.20 ± 2.6	109.05 ± 2.4 ‡

‡ Significant difference from 1-year younger age category ($p < 0.01$)

Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley; STKs, strokes; Dist, distance (yards)

The standard deviations (SD) about the means of swim times of the top 100 swimmers across ages for 7 events are shown in Figure 4 and also in Tables 11-13. SDs in the younger age categories (9&U) were relatively greater than those in the older age categories for both sexes. The smallest SD within each event was observed somewhere between the ages of 13 and 17 years in women and the ages of 14 and 18 years in men.

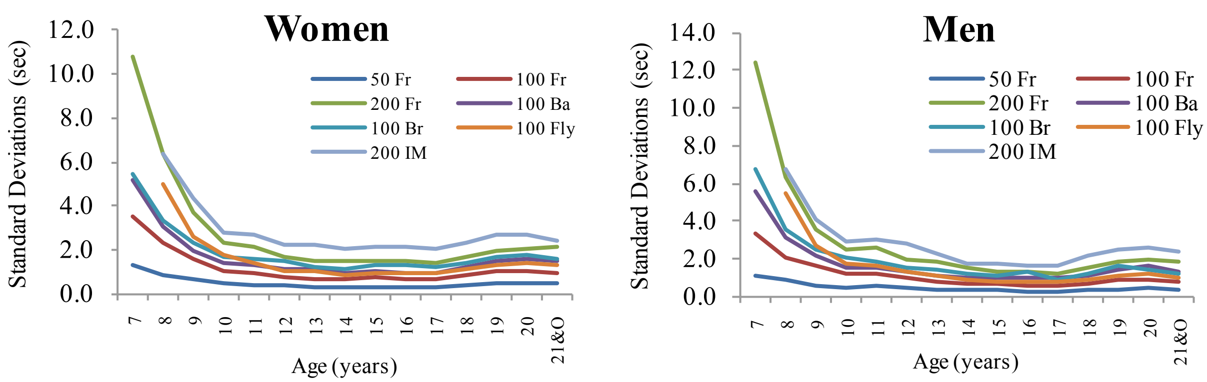

Figure 4. Standard deviations of the average times of the top 100 swimmers across ages.

Table 13. Summary of standard deviations of swim times of the top 100 swimmers across ages.

[Women]

Events		Age categories (years)														
STKs	Dist.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21&O
	50	1.3	0.9	0.7	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5
Fr	100	3.5	2.4	1.6	1.0	1.0	0.8	0.7	0.6	0.7	0.6	0.6	0.9	1.0	1.0	0.9
	200	10.7	6.4	3.7	2.3	2.1	1.7	1.5	1.5	1.5	1.5	1.4	1.7	2.0	2.0	2.1
Ba	100	5.2	3.1	2.0	1.4	1.3	1.1	1.1	1.0	1.0	0.9	0.9	1.2	1.5	1.6	1.5
Br	100	5.4	3.3	2.4	1.7	1.6	1.5	1.2	1.1	1.3	1.3	1.2	1.4	1.7	1.8	1.6
Fly	100		5.0	2.6	1.8	1.4	1.1	1.0	0.9	0.9	0.9	0.9	1.2	1.3	1.4	1.3
IM	200		6.4	4.3	2.8	2.7	2.2	2.2	2.0	2.1	2.1	2.1	2.3	2.7	2.7	2.4

[Men]

Events		Age categories (years)														
STKs	Dist.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21&O
	50	1.1	0.9	0.6	0.5	0.6	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Fr	100	3.3	2.1	1.6	1.2	1.2	1.0	0.8	0.7	0.7	0.6	0.5	0.7	0.9	0.9	0.8
	200	12.4	6.4	3.6	2.5	2.6	2.0	1.9	1.6	1.3	1.3	1.3	1.5	1.8	1.9	1.8
Ba	100	5.5	3.1	2.2	1.5	1.6	1.4	1.1	1.0	1.0	1.0	1.0	1.1	1.4	1.7	1.3
Br	100	6.8	3.5	2.5	2.1	1.9	1.6	1.4	1.2	1.1	1.3	0.9	1.2	1.6	1.5	1.2
Fly	100		5.5	2.7	1.7	1.7	1.3	1.1	0.9	0.8	0.8	0.8	0.9	1.1	1.2	1.0
IM	200		6.8	4.2	3.0	3.1	2.9	2.3	1.8	1.8	1.6	1.7	2.1	2.5	2.6	2.4

STKs, strokes; Dist, distance (yards); Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley

Progression of the differences in swim time (the average of 7 events) between adjacent ages for both sexes is illustrated in Figure 5. Each bar in the figure represents how much difference in swim performance (sec) exists between an age and one-year younger age categories. The differences became significantly smaller with an increase in CA in both sexes (r^2 = 0.82 in women and 0.85 in men). Compared with younger age categories, the differences between 17-18, 18-19, and 19-20 years old were small; they were less than 0.2 sec in women and less than 0.5 sec in men.

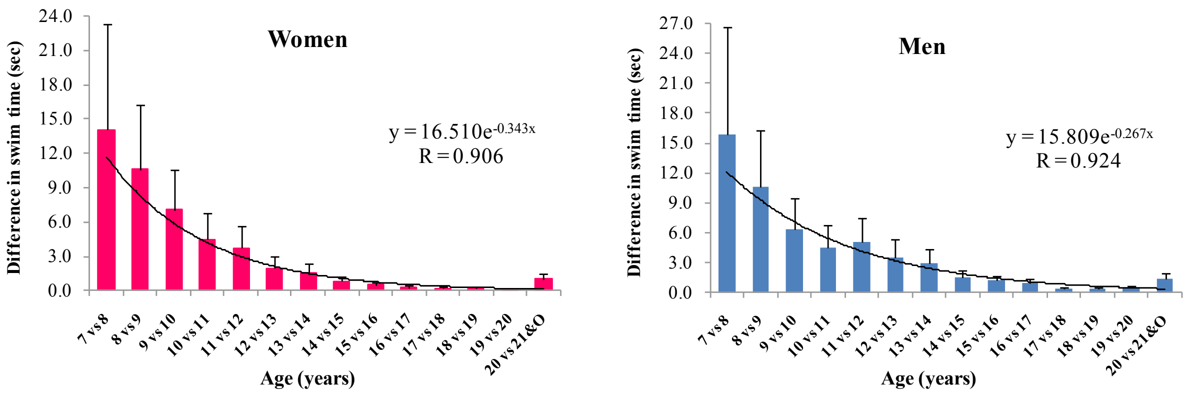

Figure 5. The differences in swim time (the average of all events) between two adjacent ages and the progression across all age categories.

Sex-Differences in Swim Performance

Significant differences in the swim times, the average of all ages (age collapse), between women and men were revealed for all 7 events (Figure 6). Men were significantly faster than women in all events. The sex-differences in swim time were 1.3 sec (4.6%) in 50 Fr, 3.0 sec (5.0%) in 100 Fr, 5.9 sec (4.8%) in 200 Fr, 3.3 sec (5.1%) in 100 Ba, 3.6 sec (4.9%) in 100 Br, 3.8 sec (6.1%) in 100 Fly, and 7.3 sec (5.2%) in 200 IM.

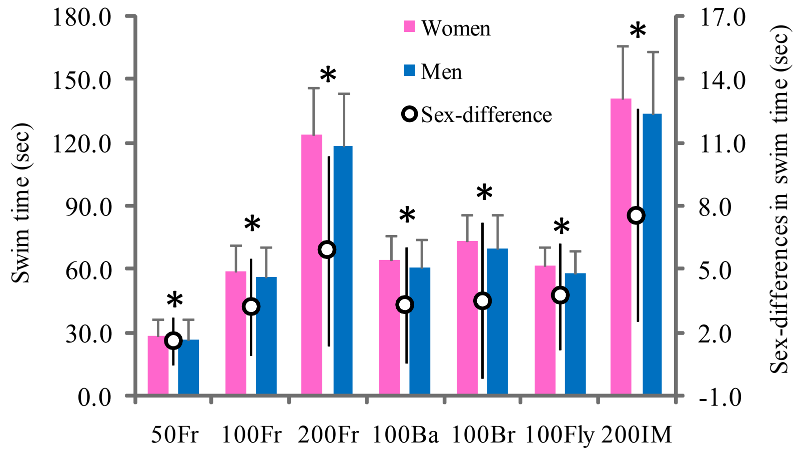

Figure 6. Comparison of the average time of 16 age categories in women with that in men for 7 evetns.
* Significant difference between women and men ($p < 0.001$).
Fr, freestyle; Ba, backstroke; Fly, butterfly; IM, individual medley; 50, 100, and 200 (yards)

Figure 7 illustrates the progression in swim performance across all CAs and the sex-differences for 7 events. Swim times became progressively faster in relation to age in men, whereas stationary progress was seen from age 18 to 20 in some of the women's events. The differences in swim time between sexes became greater with the increase in age and/or duration of swim performance in all events. Most of 8 years and older age categories revealed significance, while no significant sex-differences were found in swimmers under the age of eight in Fr events and 100-yard Ba (Figure 7 and Table 14). Br and Fly did not reveal significant sex-differences in 8- and 9-year and 8-year age categories, respectively.

The absolute (left) and relative (right) sex-differences in swim time are presented in Figure 8. The relative sex-difference (%) is expressed as the ratio of the absolute sex-difference (sec) to swim time in women. On the basis of zero shown by dashed lines, positive numbers indicate faster times in men than women, and vice versa for negative. Swim time between women and men swimmers increased as a function of age after age 11. Girls aged 11 years and under showed faster time than boys in some events, especially 100-yard Br. In the comparison of events, the absolute sex-differences became greater with the increase of duration of swim performance after the age of 11 (Figure 8, left). The differences (sec) among events were reduced when expressed as the relative difference (Figure 8, right).

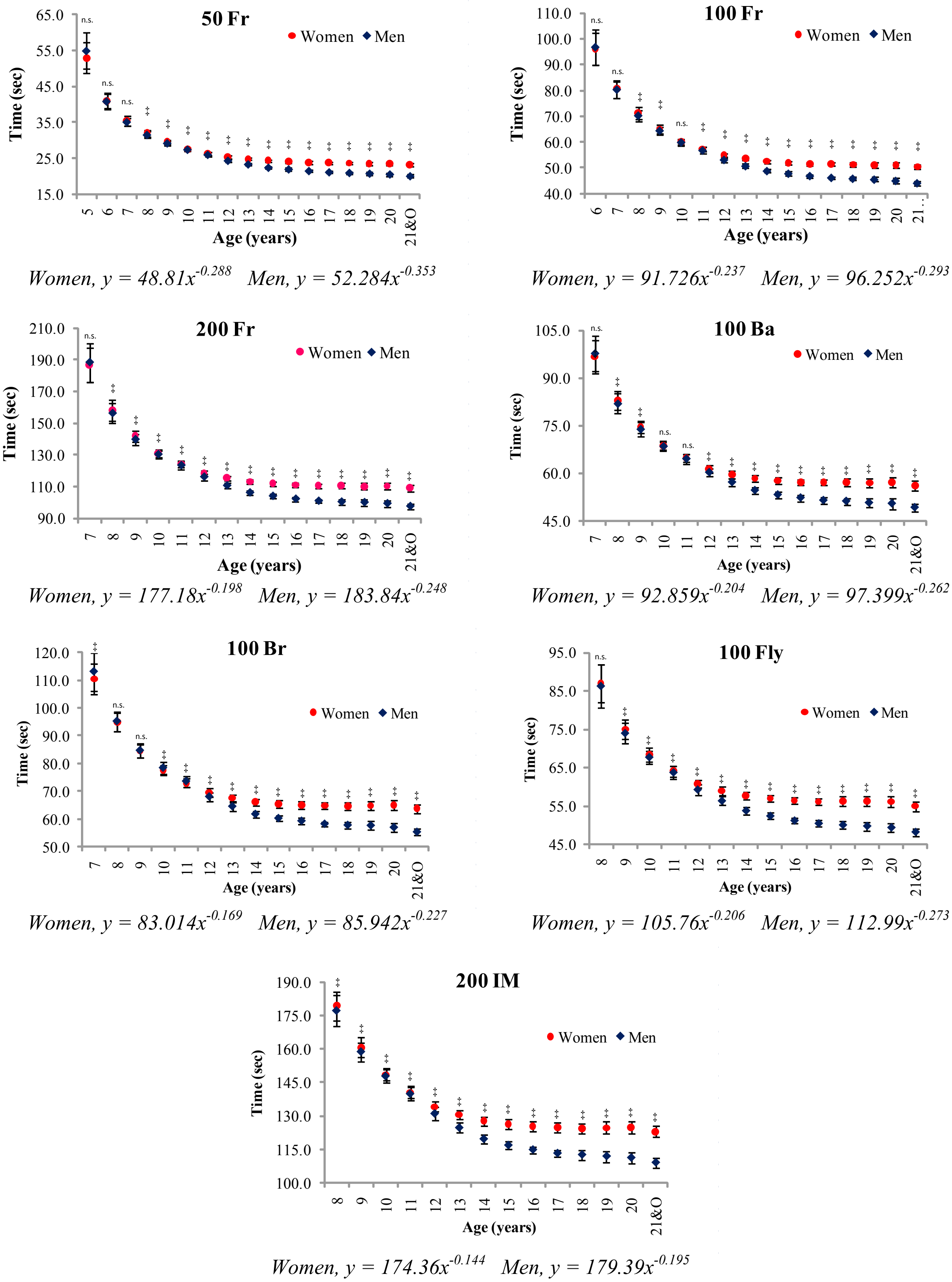

Figure 7. Progression in swim performance in women and men and the sex-related difference.
‡ Significant difference between women and men ($p < 0.01$).

Table 14. Summary of significance (p values) of the sex-differences in swim times.

Events		Age categories (yrs)																
STKs	Dist.	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21&O
Fr	50	n.s.	n.s.	.012	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
	100		n.s.	n.s.	‡	‡	n.s.	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
	200			n.s.	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
Ba	100			.014	‡	‡	.026	.030	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
Br	100			‡	n.s.	n.s.	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
Fly	100				n.s.	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
IM	200				‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡

[shaded] Difference between women and men ($p < 0.05$); n.s., not significant ($p > 0.05$)

‡ Significant difference between women and men ($p < 0.01$)

STKs, strokes; Dist., distance (yards); Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley

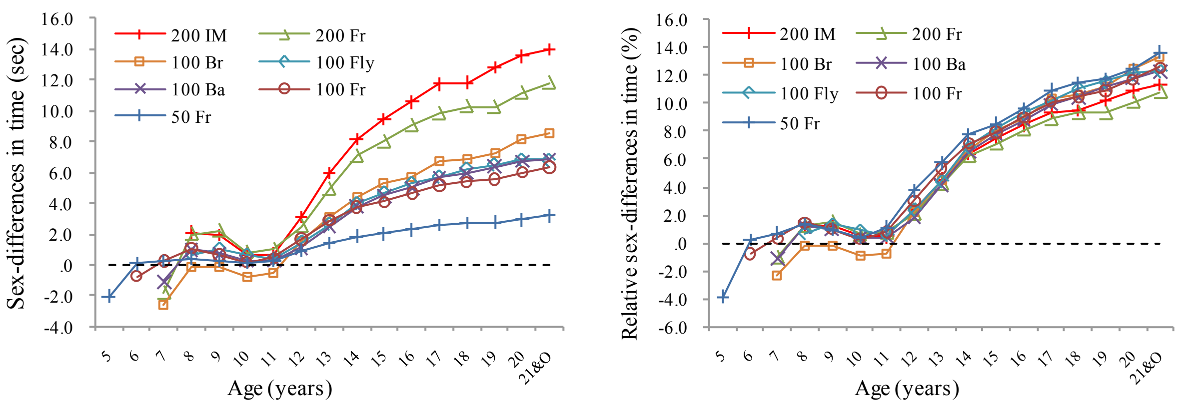

Figure 8. Sex-differences in swim performance across ages for seven events.
Left, absolute difference (sec; subtracting the swim time of men from that of women: swim time of women - men); Right, relative difference (%; the absolute sex-difference relative to that in women: sex-difference / time in women x 100). Positive values indicate that men are faster than women.
Fr, freestyle; Ba, backstroke; Fly, butterfly; IM, individual medley; 50, 50 yards; 100, 100 yards; 200; 200 yards.

Alternative Age-Groupings

The data of the statistical subsets in Table 15 correspond to data in Tables 11 and 12. Based upon Tukey's post-hoc test, homogeneous age categories are presented in Table 15. If there is a single age category in the box, the age is significantly different from all other ages ($p < 0.01$). Any age categories contained within a 'box' represent no significant difference in swim performance among them ($p > 0.01$).

Excluding 200 IM, ages up to 14 years in women and 16 years in men were independently classified into single age-groups. There was a trend for shorter distance or swim duration to have a greater number of age-groups within each box. From these data, three types of potential alternative age-groupings (subsets) for women and one for men were identified (Table 16). There is a rationale for women swimmers under the age of 15 (14&U) and for men swimmers under the age of 17 (16&U) to compete in separate age categories.

Table 15. Homogenous subsets of age categories.

Events	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15
W, 50 Fr	7	8	9	10	11	12	13	14	15	16-18	18-19	19-20	>21		
W, 100 Fr	7	8	9	10	11	12	13	14	15-16	16-18	17-20	>21			
W, 200 Fr	7	8	9	10	11	12	13	14	15-16	16-20	19->21				
W, 100 Ba	7	8	9	10	11	12	13	14	15-16	16-20	>21				
W, 100 Br	7	8	9	10	11	12	13	14	15-16,20	16-20	>21				
W, 100 Fly		8	9	10	11	12	13	14	15-16	16-20	>21				
W, 200 IM		8	9	10	11	12	13	14-15	15-17,19-20	16-20	18, >21				
M, 50 Fr	7	8	9	10	11	12	13	14	15	16	17	18	19	20	>21
M, 100 Fr	7	8	9	10	11	12	13	14	15	16	17-18	18-19	20	>21	
M, 200 Fr	7	8	9	10	11	12	13	14	15	16	17-19	18-20	>21		
M, 100 Ba	7	8	9	10	11	12	13	14	15	16	17-18	19-20	>21		
M, 100 Br	7	8	9	10	11	12	13	14	15	16	17-18	18-19	20	>21	
M, 100 Fly		8	9	10	11	12	13	14	15	16	17-18	18-19	19-20	>21	
M, 200 IM		8	9	10	11	12	13	14	15	16-17	17-19	18-20	>21		

Any age categories contained with a 'box' represent no significant difference in swim performance among them ($p > 0.01$).
The top table is for women (W) and the bottom table is for men (M); G, group; 50, 50 yards; 100, 100 yards; 200, 200 yards; Fr, freestyle; Ba, backstroke; Fly, butterfly; IM, individual medley.

Table 16. Potential alternative age-groups obtained from the study.

	G 1	G 2	G 3	G 4	G 5	G 6	G 7	G 8	G 9	G 10	G 11	G 12
Women 1	7	8	9	10	11	12	13	14	15	16-18	19&O	
Women 2	7	8	9	10	11	12	13	14	15-16	17-18	19&O	
Women 3	7	8	9	10	11	12	13	14	15-16	17&O		
Men 1	7	8	9	10	11	12	13	14	15	16	17-18	19&O

Any age categories contained with a 'box' present no significant difference in swim performance among them ($p > 0.01$).
G, group

Discussion of Findings

Age-related differences in swim performance

Hypothesis 1

Significant age-related differences in swim time were demonstrated in the study (Tables 11 and 12) suggesting the inadequacy of the current age-groupings enforced by USA Swimming. It was hypothesized that there is a significant difference in swim performance among ages. Significant differences were found between each successive CAs up to 14 years old in women and 16 years old in men for all 7 events. This result strongly recommends classifying swimmers up to those ages into single-year age-groups.

To date, Andreson & Ward (2002) have demonstrated results comparable to the present study concerning classifying competitive groups for children. The authors proposed a classification system based on anthropometric prediction of 'impulse potential'. In their study, the impulse of children aged 8.0 to 17.9 years was first calculated from vertical jump height (*h*, cm), body mass (*m*, kg), and gravity (*g*) using the equation; $I = m \times (2gh)^{0.5}$. Prediction equations for impulse scores were developed from height, weight, and limb girths (cm). The conclusion was that girls under the age of 14 might compete in separate categories, while women of 14 years and over may be able to compete together in one group due to a similar capacity to generate impulse. In boys, separate age categories were suggested up to the age of 18 years. To support these findings, literature showing a steady improvement of various motor tasks and/or continued growth and maturation among girls from 8 to 14 years old and among boys from 10 to 18 years old (Branta, Haubenstricker, & Seefeldt, 1984; Espenschade, 1963; Little & Day, 1994) was cited. However, the classification scheme of Andreson & Ward (2002) may be limited to lower-body dominant sports due to prediction equations derived from vertical jump. It requires many anthropometric measurements representing a drawback and the impracticality of the approach in a field setting.

The evolution of swim performance of non-skilled adolescent students aged 11 to 17 has been reported in relation to age and anthropometric characteristics, such as height, weight, and arm span (Pelayo, Wille, Sidney, Berthoin, & Lavoie, 1997). The adolescents (961 girls and 1097 boys) had minimum swimming sessions during a physical education program at school (6 ± 2 h/year), but no swim club practice. A 50-m front crawl (freestyle) with a push-off start was performed by the children in a 50 meter pool. The results shown in the cross-sectional study were in accordance with those of the present study showing that swim velocity increased significantly with age for both sexes ($p < 0.01$), ranging from 0.77 to 1.09 $m \cdot sec^{-1}$ in boys and 0.72 to 0.89 $m \cdot sec^{-1}$ in girls. Significant differences ($p < 0.05$) in swim velocity from an age category to the previous one (between ages) were found across all ages in boys, while significant age-related differences in girls were observed from the second or third previous age categories, but not from the previous age. Therefore, the data of Pelayo et al. (1997) indicate that boys may require separate age categories to compete, but girls of some ages can be classified into a single group. According to their data, the following age categories in girls could be potentially combined into a group: ages 11-12, 12-13, 13-15, 14-16, and 16-17 years old.

Overall improvements in sport performance in relation to age have been interpreted, in part, as changes in muscular quantity and quality, such as increases in muscle mass and anaerobic and aerobic capacities with growth (Bar-Or, 1983; Bar-Or, Unnithan, & Illescas, 1994; Boye et al., 2002; Clark, Thompson, Beck, & Jacobson, 1951; Davies, 1985; Inbar & Bar-O, 1977; Kobayashi et al., 1978; Remer, Neubert, & Maser-Gluth, 2002; Shephard, 1981, 2000). For improving sprint swim performance, maximal anaerobic power is thought to be crucial (Bar-Or et al., 1994; Carter & Ackland, 1994; Costill, Sharp, & Troup, 1980; Crowe, Babington, Tanner, & Stager, 1999; Inbar & Bar-O, 1977; Reilly & Bayley, 1988; Rohrs, Mayhew, Arabas, & Shelton, 1990; Sharp, 1986; Sharp, Troup, & Costill, 1982; Simmons, 2003; Strass, 1988; Trappe, Costill, & Thomas, 2000). It has been well documented that successful adolescent swimmers are often early maturers with increased physical size, and muscle strength, endurance, and power (Astrand et al., 1963; Kanitz & Bar-Or, 1974). These physical and physiological advantages (according to age and precocity) apparently contribute to differences in sports performance among adolescents. In addition, it may be supposed that such enhanced growth and maturity levels reflect a training effect. Precocious children may be able to better understand coaches and endure hard training compared with younger children and late maturers, which result in enhancing efficiency of training.

In conclusion, the results of the present study supported the 1st hypothesis that there is a significant difference in swim performance among ages. It is likely that growth and maturation influence and magnify the age-related differences in swim performance. It is also likely that there is a maturity-based sports performance outcome among adolescent swimmers with the current age-grouping system. The findings regarding age-related differences in swim performance obtained in the study propose the necessity for reconsideration of the current age classification enforced by USA Swimming.

Hypothesis 2

The 2nd hypothesis was that the differences in swim time between adjacent ages become smaller with the increase in CA. The present study demonstrated significant exponential progress in the differences across ages in both sexes (Figure 5). The differences were less and less with increase in age and/or as the highest swim performance is approached. The finding regarding the second hypothesis was in agreement with physical growth data, height gain and height velocity ($cm \cdot year^{-1}$) which have been well documented in the literature (Figure 9 A and B). The height gain of a child plateaus from the age of 14-15 years in girls and 16-17 years in boys as shown in Figure 9 A. In addition, from the age at PHV (on average 12 in women and 14 in men), the height gain of a child decreases with the increase in age and/or as maturity approaches. It seems to become almost zero around age 15 and 17 years in girls and boys, respectively. In the present study, differences in swim time between adjacent ages become smaller at age 15 years and 17 years in girls and boys, respectively. Also, no significant age-related differences were found after age 15 years in girls and 17 years in boys. Thus, the present data may support the link between maturity status and swim performance outcome.

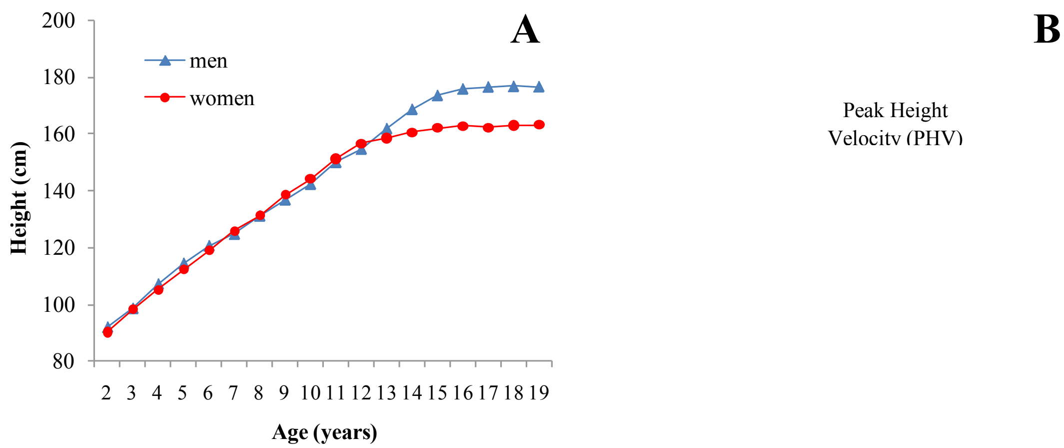

Figure 9 A and B. Height (A) across ages and height gain (B) with age in girls and boys.
A, US growth reference data (2003-2006) derived from McDowell, et al (2008)
B, A typical individual velocity curve for length or stature in girls and boys (Kuczmarski et al., 2000; Malina, Bouchard, & Bar-Or, 2004)

On the other hand, Figure 5 for boys shows that the differences between 11 and 12 year-old boys were greater than that between 10 and 11 year-old boys. When the relative improvement in swim time is expressed with one-year intervals, the percent improvement of 12 year-old boys exceeded that of 11 year-olds in all events (Table 17), which was contradictory to the 2nd hypothesis (and all other age categories in this study with the exception of 21&O groups). Although this result was not observed in women, the greater improvement at age 12 in boys might be associated with a growth and maturational phenomenon. As introduced in chapter 2 and illustrated by Figure 9, the PHV of boys is observed between the ages of 12 and 14 years, while that of girls occurs between 10 and 12 years old (Malina et al., 2004). In addition, the adolescent growth spurt is initiated, on average, between 9 and 10 years old in girls and 11 and 12 years old in boys. It has been shown that maximal oxygen intake and running performance (sec) in highly trained boys appreciably improved from the growth spurt to 2~3 years after the age at PHV (Kobayashi et al., 1978). Assuming the top 100 swimmers are early maturers, the observation of boys at age 12 in this study may not be incidental. These physical and physiological improvements with growth (growth spurt) might be associated with the findings in 12 year-old boy swimmers in this study. However, because cross-sectional data were used for the study, it fails to illuminate this maturational phenomenon.

In conclusion, the present data support the 2nd hypothesis that the differences in swim time between adjacent ages become smaller with the increase in CA.

Table 17. Relative improvement (%) of swim time across age.

Women

Events		Age (years)														
STKs	Dist.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21&O
Fr	50		9.6	7.8	6.6	4.5	3.9	2.1	1.9	1.2	0.9	0.2	0.3	0.6	0.3	1.0
	100		11.5	8.8	7.7	4.7	4.3	2.2	2.0	1.2	0.7	0.3	0.3	0.3	0.1	1.1
	200		15.2	10.3	7.6	5.1	4.7	2.6	2.0	1.1	0.7	0.5	0.1	0.2	0.2	0.8
Ba	100		14.3	10.1	7.8	5.7	5.3	2.9	2.1	1.2	0.8	0.2	0.1	0.1	0.1	1.7
Br	100		14.0	11.1	8.1	6.0	4.7	2.9	2.1	1.0	0.6	0.1	0.3	0.0	0.4	1.2
Fly	100			13.7	8.9	6.2	5.3	2.9	2.1	1.2	1.0	0.4	0.0	0.1	0.1	2.0
IM	200			10.4	7.6	5.4	4.6	2.6	2.2	1.2	0.7	0.4	0.1	0.1	0.2	1.1
mean			12.9	10.3	7.8	5.4	4.7	2.6	2.0	1.1	0.8	0.3	0.2	0.2	0.2	1.3
SD			2.3	1.9	0.7	0.6	0.5	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.4

Men

Events		Age (years)														
STKs	Dist.	7	8	9	10	11	**12**	13	14	15	16	17	18	19	20	21&O
Fr	50		10.2	7.4	6.1	5.2	**6.4**	4.2	3.9	2.1	2.1	1.7	0.9	1.0	1.1	2.3
	100		12.5	8.3	7.0	5.2	**6.4**	4.5	3.8	2.1	1.9	1.5	0.8	0.7	1.1	2.0
	200		17.1	10.6	6.8	5.3	**5.9**	4.7	4.0	2.1	1.7	1.3	0.5	0.4	0.7	1.7
Ba	100		16.3	9.9	7.3	5.7	**6.6**	5.2	4.5	2.5	1.8	1.6	0.5	1.0	0.5	2.5
Br	100		15.8	11.0	7.4	6.2	**7.6**	5.2	4.3	2.4	1.6	1.8	0.8	0.2	1.2	2.9
Fly	100			14.3	8.5	5.9	**7.0**	4.9	4.6	2.6	2.3	1.4	0.8	0.6	0.8	2.4
IM	200			10.4	6.9	5.4	**6.4**	4.8	4.1	2.3	1.7	1.4	0.6	0.6	0.6	1.9
mean			14.4	10.3	7.1	5.5	**6.6**	4.8	4.2	2.3	1.9	1.5	0.7	0.6	0.8	2.3
SD			2.9	2.2	0.7	0.4	**0.5**	0.4	0.3	0.2	0.2	0.2	0.1	0.3	0.3	0.4

STKs, strokes; Dist., distance; Fr, freestyle; Ba, backstroke; Br, breaststroke; Fly, butterfly; IM, individual medley

Hypothesis 3

The 3rd hypothesis was that there is a significant difference in swim performance within the current age-groups (10&U, 11-12, 13-14 and 15&O). This was partly explained earlier as the results were shown in Tables 11 and 12. The study found significant age-related differences in swim performance between each CA up to 14 years old in women and 16 years old in men for all events. Excluding the 200-yard IM, the significant differences were revealed through 15-and 17-year olds in women and men, respectively. Therefore, the older swimmers within each age-group are significantly faster than their younger peers, and thus have a competitive advantage, especially among swimmers aged 14 years and under (age-group swimmers). The disadvantageous situations of younger swimmers within the current age-groupings were also illustrated with Figure 1 A-D. This suggests classifying swimmers into a single-age-group at least up to the age of 14 and 16 for women and men, respectively.

With today's computing power and software sophistication, novel strategies are available to classify swimmers without affecting the meet timelines or expenses. These new innovative strategies may act to enhance competition and encourage participation rather than the converse. For instance, the current swim meets sanctioned by USA Swimming use a common operating system, Meet Manager (MM, Hy-Tek Sports Software Ltd., FL). The MM software allows the definition of customary age-groups. Therefore, it should be possible to hold a swim meet with single-age-groupings. Factors to consider are an increase in duration of a swim meet due to a greater number of heats to accommodate the increased number of age-groups (i.e., meet timelines) and increased costs for awards resulting from increase number of age-groups (i.e., meet expenses). To maintain a reasonable timeline, all participants can be seeded in heats based on their entry (seed) times, or personal best times, i.e., open age-groupings. The software can rank participants based on CA and can calculate points for individual swimmer and each team following each swimming event. In addition, for a preliminaries/finals meet, MM can rank all swimmers based on CAs and seed the top 16 swimmers for the finals and the consolation final heats immediately after the preliminaries with the open age-grouping system. Therefore, establishing and organizing many age-groups should not be difficult for the host team/organization of a swim meet. If financial issues are raised, the number of awards for events or age-groups could be reduced. For instance, the host team of a swim meet can provide the top 8 swimmers for each age with medals or ribbons, instead of the top 16 swimmers which is common throughout the nation at many meets.

This seeding system with the MM may even enhance the competitive level of a swim meet. For instance, early maturers can compete against chronologically older swimmers whose performance levels are similar. On the other hand, late maturers or beginners do not need to worry about being embarrassed by their faster peers of the same age. The only problem for these physically and technically immature swimmers may be that they must compete against chronologically younger swimmers (9 year-old vs. 14 year-old swimmers with the same swimming skill level, for example) causing psychological insult. However, the seeding system proposed here can be considered to provide a fairer and better competition to periadolescent and adolescent swimmers. In conclusion, the 3rd hypothesis that there is a significant difference in swim performance within the current age-groups was supported in the present study.

Hypothesis 4

It was hypothesized that the difference in swim time within age-groups can be reduced. Using single age (9, 10, 11 and 12 years, for example) for age classification is a better way to reduce maturity-based performance outcomes and ensure fair competition. However, if combining plural ages into a group is required by USA Swimming or the local swimming committee (LSC), one may consider changing the combination of age categories. Figure 10 A-D demonstrate an example of potential substitute "mock" age-groupings. Figure 10 A and C present the ratio (the average of seven events) of swimmers ranked in the top 40 in Indiana for each age within the current age-groups (ages of 10&U, 11-12, and 13-14 yrs), while Figure 10 B and D show the ratio using mock age-groupings (ages of 9&U, 10-11, 12-13, and 14-15 yrs). In the comparison of the current and mock age-groupings, the major difference is that 8-year-old swimmers in women (4.3%) and 7 year-old swimmers in men (0.7%) appeared and were ranked in the top 40 with the mock groupings. Although there is still a low percentage of younger swimmers within the mock age-groups, the situation observed in the current age-groupings might be improved. In older age-groups, the ratios between two ages within the mock age-groupings were closer as compared with those within the current age-groupings. For example, the ratios for women in the 13-14 current age-group were 31% vs. 69% (13 vs. 14 yrs), whereas those of the 14-15 mock age-group were 48% vs. 52% (14 vs. 15 yrs). In the men, the 13-14 current age-group showed 15% vs. 85% (younger vs. older ages), while the 14-15 mock age-group was 34% vs. 66%. A remarkable improvement was seen between the ratios of the 11-12 current age-group and the 12-13 mock age-group in boys. The ratio improved from 6% vs. 94% to 34% vs. 66% (younger age vs. older age). In conclusion, the 4th hypothesis that the difference in swim time within age-groups can be reduced was supported in this study.

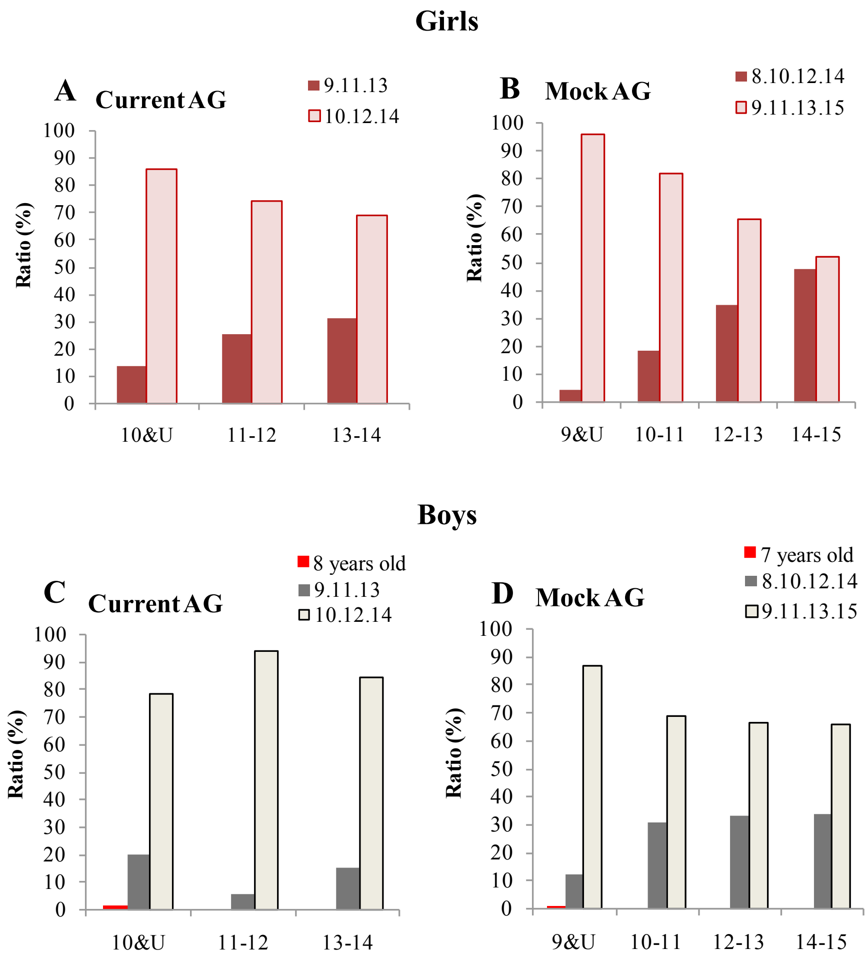

Figure 10 A-D. The comparison of the ratio of the top 40 Indiana age-group swimmers in each age within the current and mock age-groupings.
The ratio of 7 swimming events was averaged and presented.
A and C, current age-groups; B and D, mock age-groups; AG, age-group
Data from the website of USA Swimming (http://www.usaswimming.org).

Sex-differences in swim performance

The present study found significant differences in swim time between women and men in all events ($p < 0.01$, Figure 6). For the main effect of age, the sex-differences in swim performance were revealed in 8 years and older age categories in most events and 12 years and older categories in all events (Figure 7 and Table 14). Also, the difference between women and men became apparently greater in relation to age from the age of 12 years (Figure 8).

Sex-differences in growth and development have reported to be associated with those of physical performance. Differences in strength and motor performance during prepuberty are small between sexes but they are magnified during and after the boys' adolescent growth spurt (Malina et al., 2004). The continued increase in height, weight, and lean body mass (Kuczmarski et al., 2000; Malina, 1989; Malina et al., 1988; Tanner, Whitehouse, & Takaishi, 1961) during adolescence, as well as the greater increase in muscle power from puberty (Davies, 1985), have been reported in men. As discussed earlier, biological maturation in women occurs one to two years earlier than that in men, and thus physical qualities in women develop earlier (Sokolovas, 1999). These sex-differences of growth and muscular development were clearly reflected in the swim times across ages in the present study.

Pelayo et al. (1997) have demonstrated the differences in swim velocity ($m \cdot sec^{-1}$) between non skilled school girls and boys aged 11 to 17 years (a 50-m front crawl with a push-off start). In their study, swim velocity was significantly higher in boys than girls for all age categories with the exception of 12 year olds. To explain this result, anthropometric characteristics of the girls and boys at age 12 were compared and showed that the girls were significantly taller and heavier than the boys ($p < 0.05$). In addition to height and weight, arm span in the girls aged 12 years was significantly longer than the boys of the same age category. Therefore, the sex-differences in swim velocity were, in part, associated with sex-differences in size. A more precocious status in women than boys at age 12 might elucidate the sex-difference in swim velocity. After the age 12, the swim velocity of boys was consistently and significantly faster, and anthropometric values in boys were higher than the girls (Pelayo et al., 1997). The results of swim performance support the present study (Figure 8 and Table 14).

In the present study, the differences in swim time in 100-yard breaststroke (100 Br) between girls and boys at the ages of eight and nine were not significant, while all other age categories revealed its significant sex-differences (Figure 7 and Table 14). An explanation for this finding may be related to size differences between sexes. When comparing relative sex-differences in 100 Br times with those in growth reference data (height and mid-arm circumference; McDowell, Fryar, Ogden, & Flegal, 2008) across ages, the progression curves are analogous, although these data were derived from different populations (but similar years, 2003-2006; Figure 11). At the ages when girls swim the 100 Br faster than boys (between ages 7 and 11), anthropometric values are higher in girls than in boys. This agreement between sex-differences in swim performance data and growth reference data may confirm that sex-differences in growth and maturation are related to those of swim performance.

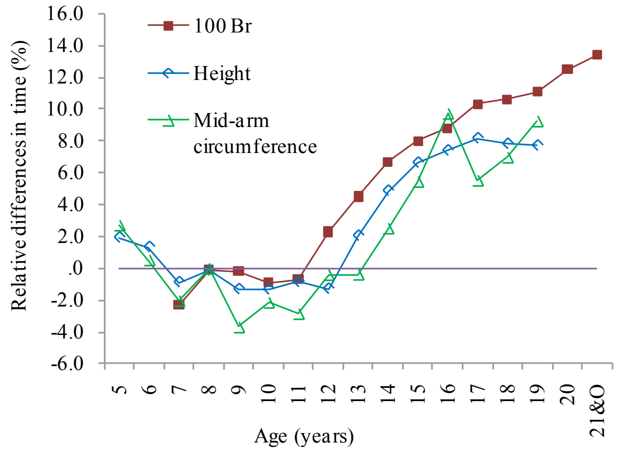

Figure 11. Relative sex-differences (%) in 100 breaststroke (Br) and growth (height and mid-arm circumference) across ages.
Positive numbers indicate boys being faster, taller, and bigger than girls. Growth reference data were obtained from McDowell, Fryar, Ogden, & Flegal (2008).

On the other hand, it is difficult to speculate why 7 through 11 year-old girls demonstrated better swim performance only in the 100 Br. Girls generally have better fine motor skills, such as coordination of small muscles, and balance and flexibility tasks during childhood to adulthood (Morris, Williams, Atwater, & Wilmore, 1982; Shephard, 2000). A child's performance characteristics are related, in part, to the child's growth, maturation, and development (Malina et al., 2004). Breaststroke is the most technical of the competitive swimming strokes because of larger resistive components, active drag (Daniel & Klauck, 1999; Kent & Atha, 1975; Kolmogorov, Rumyantseva, Gordon, & Cappaert, 1997; Soares, Sousa, & Vilas-Boas, 1999; White & Stager, 2004). Large active drag is attributable mainly to the large magnitude of the angle of attack in breaststroke (Vorontsov & Rumyantsev, 2000). Therefore, to overcome the large amount of drag, a proper technique and muscular power are important. As shown in Figure 8 (right), the greatest relative sex-differences (%) among 100-yard events are seen in breaststroke, either toward negative (i.e., women > men) or positive (i.e., women < men) values. Also, the finding of the greatest relative sex-differences seen in 21&O group swimmers whose skill and technique levels are envisaged to be similar between sexes may be supportive of the idea that the sex-differences result from those in size and power components of breaststroke. This trend is also clearly observed in freestyle events. With an increase in distance (50, 100, and 200 yards), relative sex-differences in swim time become less (Figure 12). It is known that sprint swimming events must be attributable to power and strength components (Costill, 1977). Therefore, it may be supposed that besides potentially bigger size in girls aged 7 to11 years, the more advanced maturational status of the girls at this age compared with the boys influenced the sex-differences in 100 Br in the study.

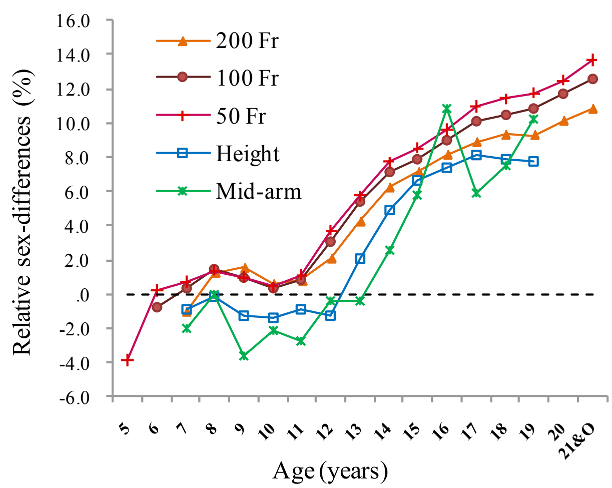

Figure 12. Relative sex-differences (%) in 50-, 100-, and 200-yard freestyle (Fr) and growth (height and mid-arm circumference) across ages.
Positive numbers indicate men being faster, taller, and bigger than women. Growth reference data were obtained from McDowell, Fryar, Ogden, & Flegal (2008).

The findings of sex-differences in swim time which progressively became greater from the age of 12 years in this study (Figure 8, 11, and 12) were also thought to result from sex-differences in growth and physical development. Also, greater sex-differences in swim performance observed in older age categories may be partly explained by differences in muscular quantity and quality. Significant sex-differences in fat-free mass (FFM) accrual in untrained and trained children from age 12 years have been well documented (Baxter-Jones et al., 2008). FFM is often considered a surrogate for skeletal muscle mass. The data show that FFM accrual between girls and boys was comparable at age 11 years but then increased more in trained boys. In addition, anaerobic power and capacity, muscular strength and endurance, and skeletal muscle mass of average women have been previously reported to attain 60-70% of average men's values (Abe, Kearns, & Fukunaga, 2003; Heyward, Johanner-Ellis, & Romer, 1986; Karlsson & Jacobs, 1980; Komi, 1980; Shephard, 1981, 2000; Wilmore, 1974). In the present study, swim performance in women swimmers attained 86 to 98% of that in men from age 12 to 21&O group. The sex-differences were less in longer distance events (Figure 8, 11, and 12).

Hypothesis 5

Due to sex-differences in timing (spurt) of growth and maturity, it was hypothesized that age-groupings in women swimmers is different from those in the men. The study found a sex-related difference in the progression of swim performance across ages. This may indicate that progression in swim performance reflect maturational differences between girls and boys. The age-related differences in swim time occur two or more years later in boys for all events when compared with girls (Table 11, 12 and 15).

Girls, on average, enter into adolescent growth spurt and reach maturity sooner than boys (Marshall & Tanner, 1986; Sokolovas, 1998). Also, as seen in Figure 9 A-B, girls stop growing in stature, on the average, by about 14-16 years of age, whereas boys continue to grow for another two or three years (Malina et al., 2004; Marshall & Tanner, 1986). These previous findings using biological, maturational, or anthropometric assessments are consistent with the results of the present study using swim times. In addition, previous studies have found little or no maturity-associated variation or improvement in motor performance between girls of different maturity status within any CA category and between girls after the age at PHV (Jones, 1949; Lefevre et al., 1988; Little et al., 1997; Malina et al., 2004). These biological and physiological features suggest that girls of different ages may be classified into a group at an earlier age compared with boys, suggesting a need for sex-specific age-groupings. In conclusion, the results in this study supported the 5th hypothesis that age-groupings in girl swimmers are different from those in the boys.

Hypothesis 6

It is well documented that during prepuberty, sex-differences in size and strength are minimal, but become more apparent during puberty/adolescence (Malina et al., 2004). Therefore, on the supposition that prepubertal girl and boy swimmers may be able to compete together, it is hypothesized that there is no significant sex-difference of swim performance in 8 years & younger age-categories. Prepubertal children are defined as children who show no overt manifestations of maturational indicators, being in the 1st stage of secondary sex characteristics (Marshall & Tanner, 1986). The age range of prepuberty has been suggested to be under the age of eight in girls and nine in boys (Malina et al., 2004). Previous studies have scarcely seen the 1st stage of secondary sex characteristics in children under the age of 9 (Guizar Vazquez, Rosales Lopez, Ortiz Jalomo, Nava Delgado, & Salamanca Gomes, 1985; Malina et al., 2004). Katch (1983) has reported small biological differences and adaptation to training (trainability) among prebubertal children resulting from the lack of hormonal control. Furthermore, Shephard (1981) showed that sex-differences in anaerobic and aerobic capacities are small prior to puberty and the differences seem to be attributable almost entirely to sociocultural factors. In addition, Shephard (2000) reported only minor or no sex-difference in physical characteristics. Costill et al. (1976) and Prince, Hikisa, & Hagerman (1977) reported no sex-difference in skeletal muscular properties through to the age of puberty. The present results demonstrated no sex-difference in swim time in 7 years and younger age categories, except for breaststroke (Figure 7 and Table 14). These results support the 6th hypothesis that girls and boys in each CA under the age of 8 can be grouped together.

Although significant age-related differences exist in swim performance among 7 years and younger swimmers for some events, there have been fewer participants aged 7 years and younger in competitive swimming throughout the nation as compared with older age categories. Table 18 shows the number of swimmers under the age of nine who enrolled in USA Swimming in 2008. It also presents the number of the USA Swimming members in California and Indiana. When considering the number of participants in a meet in Indiana for example, there are 10 to 25 swim meets per month listed on the website of Indiana Swimming. There were 21 swim meets in June 2009. Given a swimmer participates in a swim meet per month, the numbers of girls and boys aged 7 years per meet would be about 22 and 13, respectively, in June 2009. However, it may not be safe to say that all of those younger swimmers in a local swimming committee always participate in a meet. Indeed, there are a few 7 years and under swimmers in local swim meets. With the small number of participants, some questions arise: How many swimmers are needed in an event for a true swimming contest? What is the value in saying that a swimmer won the gold medal in an age-group where she/he was the only competitor? Therefore, although age-groupings stratifying swimmers by single-age categories are more likely to diminish maturity-based performance outcomes, classifying those younger swimmers into a single group may be reasonable and feasible. Thus, it may be logistically preferable that all children under the age of eight compete in a single category, age 7&U group.

Table 18. The numbers of swimmers with USA Swimming membership in two representative swimming states for 2008 season.

	Age (years)				
	4	5	6	7	8
Girls (total)	44	540	2676	>7000	>7000
California	1	29	169	340	928
Indiana	2	43	204	472	797
Boys (total)	27	409	1989	5005	6998
California		34	124	293	954
Indiana	3	26	129	275	452

total, total number of swimmers in the U.S.
Exact numbers were not available over 7000 swimmers.
> 7000, there were more than 7000 swimmers.
Data were obtained from USA Swimming website (http://www.usaswimming.org).

Alternative age-groupings and its conception

Homogeneous subsets of age categories and potential alternative age-groupings are presented in Tables 15 and 16, respectively. The data undoubtedly suggest that girls up to 14 years old and boys up to 16 years old should be classified into separate groups by single CA. In each event, girls have fewer categories than boys, and homogeneous subsets (age categories) occur two years later in boys compared with girls.

There was a trend for shorter distance events and some stroke events associated with power components, such as sprint (50 and 100 yards) freestyle, breaststroke, and butterfly, to have a greater number of categories in both sexes. Conversely, 200-yard events required fewer categories. The improvement in physiological functions associated with sports performance, for example anaerobic power, occurs with increasing CA (Beunen, 1989), as does physical size (Malina, 2000). This may suggest that late maturers are at a greater disadvantage competing against older or precocious peers in sprint and power events. In contrast, the maturational influence should be less in distance events. Therefore, it may be recommended that meets for early adolescent swimmers focus on long distance events in order to diminish maturity-based performance outcomes among the swimmers and ensure fair competition.

In addition to fair competition, youth sports organizations need to consider enhancing competition levels. For instance, combining older age categories (which demonstrated no significant difference of swim time in this study) may increase the number of competitors. Moreover, classifying swimmers based upon school grades may support the link between USA Swimming and high/middle school sports associations. It appears that elementary, middle, and high schools in the U.S. commonly partition children into 6 (6 to 12 yrs old), 2 (13 and 14 yrs old), and 4 (15 to 18 yrs old) grades, respectively. From these discussions, the 3rd potential group for women shown in Table 16 could be a better grouping system. There was only one age classification for men, but it satisfies the points discussed above.

In light of the findings in the present study, the following three factors are important to better ensure fairness and equality in competition than the current age-grouping paradigms in use today: 1) using single CA category (at least, up to age 14 years in girls and 16 years in boys), 2) sex-dependent groupings, and 3) a single unisex group for girls and boys aged 7 years and under. Alternative age classifications are proposed in Table 19 A and B. These two types of age-groupings summarize the findings of age- and sex-related differences in swim time for all events and ideas of grouping prepubertal swimmers. Both alterative age-groupings (A and B) are reasonable to be adopted in swimming although Table 19 A would be more recommended as a means of diminishing maturational differences among children. The selection may be made on the basis of the goal of the competition; whether a swim meet designs fairness in competition or higher levels of competition or both.

Table 19 A and B. Alternative age classification.

<table>
<tr><th>A</th><th>G1</th><th>G2</th><th>G3</th><th>G4</th><th>G5</th><th>G6</th><th>G7</th><th>G8</th><th>G9</th><th>G10</th><th>G11</th><th>G12</th></tr>
<tr><td>Women</td><td rowspan="2">7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15-16</td><td>17-18</td><td>19&O</td><td></td></tr>
<tr><td>Men</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17-18</td><td>19&O</td></tr>
</table>

<table>
<tr><th>B</th><th>G1</th><th>G2</th><th>G3</th><th>G4</th><th>G5</th><th>G6</th><th>G7</th><th>G8</th><th>G9</th><th>G10</th><th>G11</th><th>G12</th></tr>
<tr><td>Women</td><td rowspan="2">7</td><td rowspan="2">8</td><td rowspan="2">9</td><td rowspan="2">10</td><td rowspan="2">11</td><td>12</td><td>13</td><td>14</td><td>15-16</td><td>17-18</td><td>19&O</td><td></td></tr>
<tr><td>Men</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17-18</td><td>19&O</td></tr>
</table>

Chapter 5

SUMMARY, FINDINGS, CONCLUSIONS, IMPLEMENTATIONS AND RECOMMENDATIONS

Summary

The problems addressed in this study were 1) whether or not the current age-groups established by USA swimming are appropriate as a means of providing fair competition; 2) whether or not more appropriate competitive groupings, based upon CA, can be proposed; 3) whether or not sex-specific age-grouping systems are necessary due to sex-differences in timing of the adolescent growth spurt and maturity; and 4) whether or not the age of eight and under (prebubertal) swimmers should be classified into separate unisex categories.

Swim times of the top 100 U.S. women and men swimmers for each age (5 yrs to 20 yrs) and a group of 21 yrs and over (a total of 17 separate age-groups for each sex) were acquired through the website of USA Swimming for 2005, 2006, and 2007. Data for each age were pooled over the past three years (2005-2007) and averaged for 7 swimming events (50-, 100-, and 200-yard freestyle, 100-yard backstroke, breaststroke, and butterfly, and 200-yard individual medley).

The data were analyzed using univariate analysis of variance (ANOVA). A 17 × 2 × 7 (age × sex × event) ANOVA with Tukey's post-hoc test was used to analyze the differences in swim time among age categories and to provide alternative age-groupings. SPSS 16.0 was used for all statistical analysis.

Findings

The study revealed the following significant findings:

1. There were significant age-related differences in swim performance between each CA up to 15 yrs old in women and 17 yrs old in men for most events, and 14 yrs in women and 16 yrs in men for all events.

2. Older swimmers within the current age-groupings were significantly faster than the younger swimmers.
3. Significant exponential progress in swim performance was revealed for all events in both sexes. (The differences in swim time between adjacent ages became smaller with the increase in age.)
4. The age-related differences in swim time occurred later in men when compared with women.
5. Swim times in women were significantly slower when compared to those in the men.
6. Sex-differences of swim time between 12- and 20-year age categories became greater with the increase in age or when the highest performance approaches.
7. No significant sex-difference in swim time was found in 7 years and under age categories.
8. Significant sex-differences in swim time were revealed in 12 years and over age categories for all events.

Conclusions

Within the limitations of the study the following conclusions are warranted:

1. Due to age- and/or maturation-associated performance outcomes in swimming, USA Swimming needs to reconsider the current age-groupings to ensure fair competition by stratifying swimmers using single CA at least up to 14 year-old in girls and 16 year-old in boys.
2. Due to the sex-dependent patterns of age-related differences in swim time, adopting sex-specific age-groupings is necessary.
3. In order to take into account higher levels of competition among younger swimmers, combining sexes in age categories (7 years & under or possibly 11 years & under) may be appropriate.

Implementations

The findings of the study may be implemented into either a practice situation or a field setting in the following ways:

1. The implementation of grouping swimmers by single age reduces maturational influence on performance outcomes and possibly provides fair competition and more chances of success to all swimmers. The single age-grouping system and seeding system based on times proposed in the study are accommodating for practical situations, i.e., swim meets, due to no extra work and effort, associated with anthropometric measurement and performance testing.
2. Since no universal classification system for children in youth sports exists beyond CA, the use of the alternative age-groupings with sex-specific classification must be supportive of further development and prosperity of age-group swimming and of age-group swimmers who will be inclined to drop out.
3. In addition to the age classification proposed in the study, competition levels could be enhanced by seeding heats based upon swim times regardless of age (open age categories) and combining girls and boys in younger age categories (7 or 11 years and under) into unisex groups.

Recommendations for Further Study

The following recommendations are made for further research in the area of youth sports classification in individual sport events:

1. The present study should be conducted with different swimming populations in the U.S. but not the top 100 swimmers, for example, 200-300th swimmers in the U.S. or the top 40 swimmers for each age category in a state. Due to a report demonstrating a link between successful, elite adolescent swimmers and early maturers, the higher ranked swimmers during early to mid adolescent periods are thought to be associated with early/advanced maturing (Bar-Or, Unnithan, & Illescas, 1994). Thus, using lower ranked swimmers may provide different perspectives on alternative age-groupings from those in this study.

2. The present study should be replicated using swimmers in other swimming countries or different youth sports athletes, such as track and field.
3. To replicate the present study, use of more sophisticated statistical analysis is recommended. For example, Monte carlo simulation methods are useful for research with a large number of coupled degrees of freedom.
4. A longitudinal study using swim times on USA Swimming's website may provide a different perspective on age-related differences in swim performance.
5. A study should be conducted to determine the cause and effect relationship between maturational status and swim performance outcomes: for instance, the influences of maturational differences on swim performance among age-group swimmers using biological assessments.
6. As varying among children, maturity status (levels of maturity in time, timing, and tempo) may considerably vary among races. For instance, there seems to be ethnic variation in the average ages at the initiation of growth spurt, PHV, and menarche among children in different countries (Burrows, Baxter-Jones, Mirwald, Macdonald, & McKay, 2009; Floyd, 1998; Kobayashi et al., 1978; Malina et al., 2004). Consequently, due to the recent promotion and the prevalence of international youth sports competition based on CA-based groupings and CA limit, there may be maturity-based performance outcomes even in top elite youth levels. Thus, it may be interesting to see whether or not there are racial differences in parameters of the adolescent growth spurt and biological/maturational indicators and whether or not the differences impact on sports performance outcomes at international youth championships. Furthermore, it may be fascinating to investigate factors (genetic, environmental, and etc.) causing the racial differences.

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[Swimming Federations]

Fédération Internationale de Natation: http://www.fina.org

FINA rules:

http://www.fina.org/project/index.php?option=com_content&task=view&id=670&Itemid=119

Swimming Australia: http://www.swimming.org.au

British Swimming: http://www.britishswimming.org

Swimming Canada: http://www.swimming.ca

Chinese Swimming Association: http://swimming.sport.org.cn

Chinese Taipei Swimming Association: http://www.swimming.org.tw

Deutscher Schwimm-Verband e.V.: http://www.dsv.de

Japan Swimming Federation: http://www.swim.or.jp

Swimming New Zealand: http://www.swimmingnz.org.nz

Real Federación Española de Natación: http://www.rfen.es

USA Swimming: http://usaswimming.org

Indiana Swimming: http://inswimming.org

Central California Swimming: http://www.centralcalswim.org

Southern California Swimming: http://www.socalswim.org

APPENDIX A: HUMAN SUBJECTS CONSENT FORMS

INDIANA UNIVERSITY

OFFICE OF RESEARCH ADMINISTRATION

To: Kosuke Kojima
Kinesiology

From: IUB Human Subjects Office
Office of Research Administration – Indiana University

Date: December 19, 2008

RE: **EXEMPTION GRANTED**
Protocol Title: Age Classifications in USA Swimming: Are Adolescent Swimmers Competing in Equalized Competitions?
Protocol #: 08-13480
Sponsor: N/A

Your study named above has been accepted as meeting the criteria of exempt research as described in the Federal regulations at 45 CFR 46.101(b), paragraph 4. This approval does not replace any departmental or other approvals that may be required.

As the principal investigator (or faculty sponsor in the case of a student protocol) of this study, you assume the following responsibilities:

- Changes to Study: Any proposed changes to the research study must be reported to the IRB prior to implementation. This may be done via an e-mail or memo sent to the IRB office. Only after approval has been granted by the IRB can these changes be implemented.

- Completion: Although a continuing review is not required for an exempt study, you are required to notify the IRB when this project is completed. In some cases, you will receive a request for current project status from our office. If we are unsuccessful in our attempts to confirm the status of the project, we will consider the project closed. It is your responsibility to inform us of any changes to your contact information to ensure our records are kept current.

Per federal regulations, there is no requirement for the use of an informed consent document or study information sheet for exempt research, although one may be used if it is felt to be appropriate for the research being conducted. As such and effective immediately, the IUB IRB will no longer stamp study information sheets / informed consent documents for exempt research. Please note that if you still choose to use these documents, you may use unstamped versions. **Please note that your study has been accepted without the use of a study information sheet**.

You should retain a copy of this letter and any associated approved study documents in your records. Please refer to the project title and number in future correspondence with our office. Please contact our office at (812) 855-3067 or by e-mail at iub_hsc@indiana.edu if you have questions or need further assistance.

Thank you.

RECEIVED
SEP 29 2008
HUMAN SUBJECTS COMMITTEE

INDIANA UNIVERSITY – BLOOMINGTON INSTITUTIONAL REVIEW BOARD (IRB) REVIEW
EXEMPT RESEARCH CHECKLIST

IRB Study #: 08-13480
(IRB Office will assign)

SECTION I: INVESTIGATOR INFORMATION

Principal Investigator: Kojima, Kosuke T 9/23/06, COI 9/29/08 **Department:** Kinesiology
(Last, First, Middle Initial)

Building/Room No.: HPER 104 Phone: 812-856-7164 E-Mail: kokojima@indiana.edu

Faculty Sponsor: Stager, Joel M T 10/5/06, COI 9/9/08 **Department:** Kinesiology
(Last, First, Middle Initial)

Building/Room No.: HPER 032 Phone: 812-856-7164 E-Mail: stagerj@indiana.edu

Project Title: Age classifications in USA swimming: are adolescent swimmers competing in equalized competitions?

Sponsor/Funding Agency:

SECTION II: PERFORMANCE SITE

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☒ Indiana University Bloomington Campus; state location(s):

☐ Other Indiana University Campus: state location(s):

☐ Anthropology
☐ Bloomington Hospital
☐ Bradford Woods
☐ School of Business
☐ Economics
☐ School of Education
☐ French and Italian
☐ Gender Studies
☐ Health Center
☒ Health, Phys Ed & Rec (HPER)
☐ IN Institute on Disability & Communication
☐ Informatics
☐ School of Journalism
☐ The Kinsey Institute
☐ Library General
☐ School of Library & Info Science
☐ MCCSC (Monroe School District)
☐ School of Music
☐ Nursing
☐ Optometry
☐ Population Institute for Research & Training
☐ Department of Psychology and Brain Sciences
☐ Second Language Studies
☐ Sociology
☐ Spanish & Portuguese
☐ Public & Environmental Affairs (SPEA)
☐ Speech and Hearing Sciences
☐ Center for Survey Research
☐ Telecommunications
☐ University Info Tech Services
☐ Center for Evaluation and Education Policy
☐ Central Eurasian Studies
☐ Communication and Culture
☐ Computer Science
☐ Criminal Justice
☐ Folklore and Ethno Musicology
☐ History
☐ Linguistics

☐ Other:

SECTION III: RESEARCH DESCRIPTION

1. Provide a brief description, in lay terms, of the purpose of the proposed project and the procedures to be used.

The pupose will be to examine and confirm the adequacy of current age classifications adopted by USA Swimming by evaluating and comparing swim performances. Data base (swim times) on the website of USA Swimming will be utilized to statistically analyze the research question.

a. Please state the eligibility (inclusion/exclusion criteria.