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Classifying Children for Sports Participation Based Upon Anthropometric Measurement

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Purpose: This study proposes a classification system for youth sports that is maturation-based, using the anthropometric prediction of vertical jump impulse potential. Methods: Impulse was calculated for children between 8.0 and 17.9 years of age from vertical jump height [$I = m \times (2gh)0.5$] in a truncated version of the Coquitlam Growth Study database. A series of stepwise regressions was performed for each gender, predicting impulse scores from 32 anthropometric variables, height, body mass, and chronological age. Results: Equations were developed that accounted for differences in muscle tissue development while utilizing variables easily measured in both males and females, including age, and measures of height, forearm girth, and calf girth. Conclusion: Using restricted ranges of impulse scores, males and females can be classed into appropriate groups for competition and sport, competing together through the age of 13. Beyond the age of 14, females have a similar capacity to generate impulse and could compete in one group, while restricted impulse categories would be useful for males until the age of 18 years.

Key Words: sports, competition, maturation, impulse

Key Points:

1. The limitations of classifying children and youth for sports participation based on chronological age have been a point of discussion for nearly a century.
2. The present study reports a classification system based upon simple, easily obtained anthropometric measures.
3. The underlying tenet of the present study is that classification schemes for youth sport have to be developed on factors beyond the individual's control, avoiding the use of body mass, while representing the individual's gross ability to generate force.
4. Gender specific equations are presented for the classification of youths based on impulse potential, predicted from anthropometric variables.
5. Data suggest that males and females may well be able to compete together up to the age of 14 years, based on impulse potential, after which males and females might compete in separate groups from the age of 14 to 18 years.

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Competitive sports make up a large portion of curricular and non-curricular physical activity opportunities for children and adolescents. Matching participants in these environments is typically performed on the basis of chronological age, sex, skill level and, in some combative sports, body mass. The most common practice in amateur sport is to group on the basis of chronological age, placing children into categories based on 2-year intervals. However, the limitations of this approach have been discussed for the last 100 years. For example, in 1908 Crampton advocated the use of “physiological age” based on the assessment of pubic hair development, while in 1909 Rotch advocated for the use of “anatomic age” based on x-ray and carpal development (19). Both of these authors recognized that differences in maturation could be related to the wide range observed in mass, height, strength, power, and skill at any single chronological age.

More recent research demonstrates that children of advanced physical maturity are able to perform a variety of physical and motor tasks more proficiently as compared to children of retarded maturational status (2, 3, 11, 13, 17, 25). These results sparked a renewed interest in the classification of children into equitable groupings. Classification systems were proposed for testing physical abilities in school systems and for grouping athletes for participation in competitive sports; however, Mirwald et al. (22) suggest the equitable classification of youth for the purpose of sports participation remains an important, but unresolved, issue. While the issues surrounding youth sport classification systems are evident in today’s literature, no universal classification system for children in youth sports exists beyond chronological age.

While early attempts to classify children in physical education and athletics have been based on age, height, body mass, and gender (8, 24), in recent years there has been some controversy over the use of body mass in classification scores and concern over the efficacy of the various classification systems in use. For example, Tipton et al. (29) strongly advised against the use of broad weight classes in wrestling, as the system encourages the athletes to lose weight in order to wrestle in a lighter weight class. Roemmich and Rogol (25) suggest that competitors in weight-restricted categories often lose 5% to 10% of their body mass prior to weighing in for competition in weight class events. Further, the very low caloric diets, inadequate hydration, and excessive exercise related to this weight loss is not healthy in adolescence, as these tendencies are linked to lower levels of circulating testosterone as well as growth hormone resistance (25).

An alternative to chronological age and weight-restricted categories is maturation-based classification. Traditional maturation-based categorization is based upon skeletal age and/or secondary sex characteristics (5, 15, 16, 22, 25). Determination of skeletal age, however, is expensive, and requires an annual dose of radiation and the aid of a highly skilled technician for bone calcification ratings. The use of Tanner genital stages, while not requiring an x-ray, invades the participant’s privacy, causes the participant undue stress, and also requires a highly trained assessor. The traditional maturation assessment strategies are “invasive, intrusive, and/or gender specific” (22: p. 694). For this reason several individuals have predicted maturational status from variables linked to the growth and maturation process (22, 30).

Ward et al. (30) suggest that a classification system based on the abilities of the athletes to generate force (or impulse), reflecting their progress towards neural and muscular maturity (30), may be an alternative to the traditional classification systems. It was thought that such a system would reduce the number of injuries in competitive team sports (5, 16) and increase participation and enjoyment by allowing children to compete with peers capable of generating similar force and impact potential.

This study develops a system for the classification of both boys and girls into equitable competitive groupings based upon the premise that it is desirable to group individuals according to their impulse potential. However, physical performance tests through which impulse can be calculated, such as the vertical jump or medicine ball putt, are within the individual's control and can be largely influenced by motivation. In a classification system based upon physical performance, the individual could purposefully manipulate performance to change classification level. For this reason, the present study develops a classification system based on the anthropometric prediction of impulse, and compares age restricted and predicted impulse categorization of youth for sport participation.

Methods

The present study uses the anthropometric and performance data collected on 386 boys and 352 girls, ages 8.0 through 17.9 decimal years (Table 1). Written informed consent was obtained from the parent or guardian of each child, with the study being approved by the institutional research ethics committee. The data presented represents a portion of the Coquitlam Growth Study (COGRO) database, as reported in Ross and Marfell-Jones (27) and Ross et al. (26). Key anthropometric and performance data are reported in Table 1, including body mass (WT), height (HT), forearm girth (FAG), calf girth (CAG), vertical jump height (VJ), and calculated impulse (IMP).

Vertical jump height was measured using a waist harness and pull-through measuring tape methodology as illustrated in Figure 1. Each subject wore a tightly fitting waist harness attached to a flexible wide measuring tape that threaded through a metal fitting attached to the floor. The tape could easily slide through the fitting with minimal resistance. The subject was asked to rise up on to his or her tiptoes (the assumed takeoff position), and the reading was taken on the tape measure at the edge of the metal fitting on the floor. The subject then performed the vertical jump from a squat position with arm swing but without countermovement. During the up phase of the jump, the tape traveled through the metal fitting and stopped at the peak of the jump. After the subject had landed, peak height could be measured at the edge of the metal fitting. The vertical jump height was then calculated as the difference between the measurements before and after the jump.

Impulse (I) was then calculated from the greatest jump height achieved in each of three trials for each of the children within the truncated COGRO database. Impulse is calculated as the product of mass (m) and the square root of twice the acceleration due to gravity (g) times the vertical jump height from the point of takeoff (h), as in the equation:

$$I = m \times (2gh)^{0.5}$$

As calculated impulse from vertical jump height was to be the criterion measure by which children would be classified, the reliability and validity of calculated impulse was evaluated in a separate sample of 28 males between the ages of 12 and 16 years of age. Each child performed three vertical jump trials while situated upon

Table 1 Key Anthropometric and Performance Data for Individuals in the Coquitlam Growth Study at Ages 8 Through 17

Females Age	n		Mass (kg)	Height (cm)	FAG (cm)	CAG (cm)	VJ (cm)	Impulse (kg cm sec^{-1})
8	24	mean	26.2	129.4	18.6	25.5	24.5	572.8
		sd	3.5	5.1	1.1	1.8	5.4	110.1
9	20	mean	32.1	136.7	20.1	27.6	28.3	753.6
		sd	5.8	6.0	1.3	2.1	6.2	169.1
10	28	mean	37.0	144.6	21.0	29.3	30.8	908.2
		sd	8.7	8.5	1.8	3.3	6.0	254.2
11	31	mean	41.6	148.9	21.2	30.1	31.8	1030.4
		sd	10.4	9.2	1.9	3.0	6.9	270.0
12	27	mean	44.5	155.8	21.9	31.3	34.4	1150.2
		sd	7.1	6.8	1.5	2.2	4.9	177.9
13	55	mean	51.6	161.1	23.1	33.3	37.8	1394.8
		sd	10.0	6.4	1.7	3.1	8.1	282.9
14	66	mean	52.7	162.9	23.4	33.9	40.1	1465.4
		sd	8.8	6.2	2.0	2.7	7.8	259.4
15	65	mean	53.8	163.4	23.5	34.0	39.1	1486.2
		sd	8.3	6.6	1.4	2.7	7.4	265.1
16	27	mean	54.9	165.3	23.6	34.2	33.9	1406.0
		sd	6.7	5.3	1.5	2.3	6.4	185.4
17	9	mean	55.6	164.0	23.9	34.2	34.0	1433.6
		sd	3.7	4.0	1.3	1.5	5.2	178.3
Males								
8	28	Mean	28.5	132.0	19.6	26.9	27.4	654.5
		sd	5.4	7.6	1.5	3.0	6.2	138.1
9	19	mean	30.1	135.7	19.9	26.9	27.5	695.1
		sd	4.1	6.6	0.9	1.4	3.7	82.2
10	21	mean	35.9	142.8	21.1	28.9	32.7	905.0
		sd	7.6	7.1	1.7	2.9	4.5	191.7
11	35	mean	40.8	147.3	22.1	30.0	35.2	1069.6
		sd	9.2	7.0	2.0	3.0	5.9	253.5
12	25	mean	45.1	155.3	23.0	31.9	36.6	1204.8
		sd	8.8	9.3	1.8	2.8	8.3	290.5
13	57	mean	49.8	161.8	23.9	32.6	42.2	1424.6
		sd	9.5	8.8	1.8	2.7	7.2	282.9
14	82	mean	56.1	168.1	25.1	33.9	42.6	1623.9
		sd	11.2	8.6	2.0	3.1	8.0	387.2
15	62	mean	59.2	171.8	25.7	34.0	45.0	1755.3
		sd	9.4	8.3	1.8	5.1	6.8	308.2
16	33	mean	62.3	175.7	26.5	35.6	46.8	1880.5
		sd	6.0	6.3	2.0	2.0	7.4	225.6
17	24	mean	67.4	178.0	27.2	36.1	46.3	2025.9
		sd	9.9	7.9	1.4	3.1	7.4	329.9

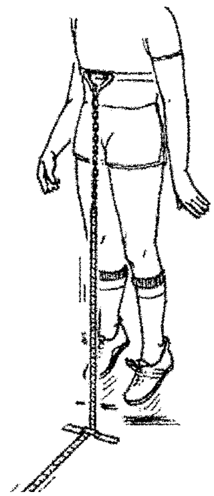

Figure 1 —Determination of vertical jump height.

a force platform. The harness pull-through method was used, with the metal fitting attached to the center of the force platform, thus allowing simultaneous tape measure measurements and force platform recordings. Two values of impulse were then calculated independently from height jumped and from the integrated force plate recordings. Correlation coefficients were calculated for each of the jump/platform trials, and differences between the means were investigated using paired *t* tests.

For the COGRO data, using calculated impulse as the criterion measure, a series of SPSS stepwise multiple regressions were performed for each gender, predicting impulse scores as calculated from vertical jump height and mass, 32 anthropometric variables, height, and chronological age (reported in decimal years). Anthropometric variables included 8 projected lengths, 6 skinfolds, 11 girths, 3 trunk breadths, 2 bone breadths, foot length, and anterior–posterior chest measures (20). In the first stepwise regression analysis, the entry of variables were not controlled. In the second run of the regression, chronological age (reported in decimal years) was forced to enter first, and variables were eliminated that were deemed inappropriate for wide-scale use, or over which individuals could exert volitional control (chest girth in females and flexed arm girth in males). The rationale for this was that age is easily verified, and the measure essentially has no technical error of measurement, while chest girth and flexed-arm girth have large technical errors of measurement. In fact, for psychosocial reasons, chest girth may be an inappropriate measurement, being stressful for both the young females and the person taking the measure at the "registration desk." These modifications reduce the technical error introduced into the regression equation while simplifying the measures that practitioners are required to obtain. Final regressions were performed using height, age, forearm girth, and calf girth in both male and female subgroups.

Impulse categories were developed from examining the mean overlap between impulse scores in males when classified into typical age restricted categories.

(As impulse reaches a plateau in females beyond 13 years of age.) Impulse categories were calculated to be 0–209 kg cm ∑ s^{-1}, 210–319 kg cm ∑ s^{-1}, 320–439 kg cm ∑ s^{-1}, 440–539 kg cm ∑ s^{-1}, 540+ kg cm ∑ s^{-1}. The age-restricted categories and the impulse classification systems were then compared to examine the percentage of the individuals in each age-restricted category who would not fall within the impulse classification scheme.

Results

Predicted impulse correlated well with force platform measures of impulse on each of the three trials (r = .86 to .92). Impulse, as determined by vertical jump performance and mass, significantly underestimated the impulse as determined from the force platform (mean difference = 11.7 kg cm ∑ s^{-1}; $t = 3.85$, $p < .01$). This may well represent a systematic measurement error, as the overall correlation between the two measures of impulse remained high at .90 (which was as good as the repeatability of the force platform measures).

Investigating differences between trials shows the impulse generated on trial 3 of the vertical jump to be significantly better than that of both trial 1 ($p < .01$) and trial 2 ($p < .01$), while the impulse calculated from force platform measures did not vary significantly between trials ($p > .05$). The mean impulse (SD), as calculated from the vertical jump performance and force platform measures, is presented in Table 2.

Using calculated impulse as the criterion measure, and anthropometric data from the Coquitlam Growth Study, stepwise multiple regressions were performed using SPSS software, developing a series of equations for both males and females. The first regression analysis for each gender (see Table 3) allowed SPSS to produce the single best prediction of calculated impulse from all anthropometric variables; the second equation forced decimal year age into the equation (no technical error of measurement); the third equation was developed to account for gender differences in muscle development while presenting variables easily measured in both males and females (including age, height, forearm girth, and calf girth). These last equations are those proposed for general use:

$$\text{Males: Impulse} = -2895.3 + 10.48(\text{HT}) + 16.25(\text{age}) + 74.78(\text{FAG}) + 19.27(\text{CAG})$$

Table 2 Mean Impulse (standard error) As Determined From Vertical Jump Performance and a Force Platform, Reported in kg cm sec^{-1}

		Trial 1	Trial 2	Trial 3
Vertical jump		164.9	163.9	171.6
	s.e	7.1	6.5	7.2
Force platform		178.7	181.6	182.5
	s.e	6.9	6.3	7.4
Correlation	*r*	0.92	0.86	0.90

Table 3 Summary of Variables Entered Into Regression Equations

	HT	Age	FAG	CAG	AGF	CHG	r	s.e.e.
Male								
Eq. 1	**X**		**X**		**X**		0.95	161.1
Eq. 2	**X**	**X**	**X**				0.94	169.9
Eq. 3	**X**	**X**	**X**	**X**			0.94	166.8
Female								
Eq. 1	**X**			**X**		**X**	0.92	146.1
Eq. 2	**X**	**X**		**X**			0.91	152.7
Eq. 3	**X**	**X**	**X**	**X**			0.92	152.3

HT = height; Age in decimal years; FAG = forearm girth; CAG = calf girth; AGF = flexed arm girth; CHG = chest girth.

$$\text{Females: Impulse} = -2378.0 + 9.63(\text{HT}) + 7.71(\text{age}) + 14.88(\text{FAG}) + 52.61(\text{CAG})$$

The mean impulse (with the range of scores), as calculated from vertical jump height for typical age-restricted categories, is presented in Figure 2. Table 4 presents data demonstrating the degree to which age restricted categorization of the children in the COGRO database coincide with the developed impulse classification categories for gender and in a combined sample.

Discussion

A fundamental goal in youth sport is to enhance participation and allow participants to enjoy positive experiences, thereby developing patterns of physical activity that carry over into adulthood. To facilitate this, players are typically grouped within narrow age ranges and games are modified to ensure that the athletes can enjoy success (e.g., modify implement size and/or body mass). However, the use of chronological age-restricted categories for sport participation has been the topic of debate over the better part of the century, with age-restricted categories offering only a partial solution to the categorization of children. The fundamental problem with age-restricted categories is that chronological age is only a general indicator of developmental status (20). During adolescence, children of similar chronological age may vary significantly in their progress toward the mature adult form and therefore may exhibit great size and strength differences that complicate the problem of matching children for sport participation.

In an analysis of youth hockey, Roy et al. (28) compared 8 small and large individuals playing contact hockey in Quebec, Canada. The athletes were of the same chronological age (13.5 years), but differed substantially in mass (37.1 vs. 74.3 kg), height (147.4 vs. 178.9 cm), combined right- and left-hand grip strength (54.1 vs. 110.1 kg), maximal skating speed (7.6 vs. 8.3 m/s), and impact force (1,010

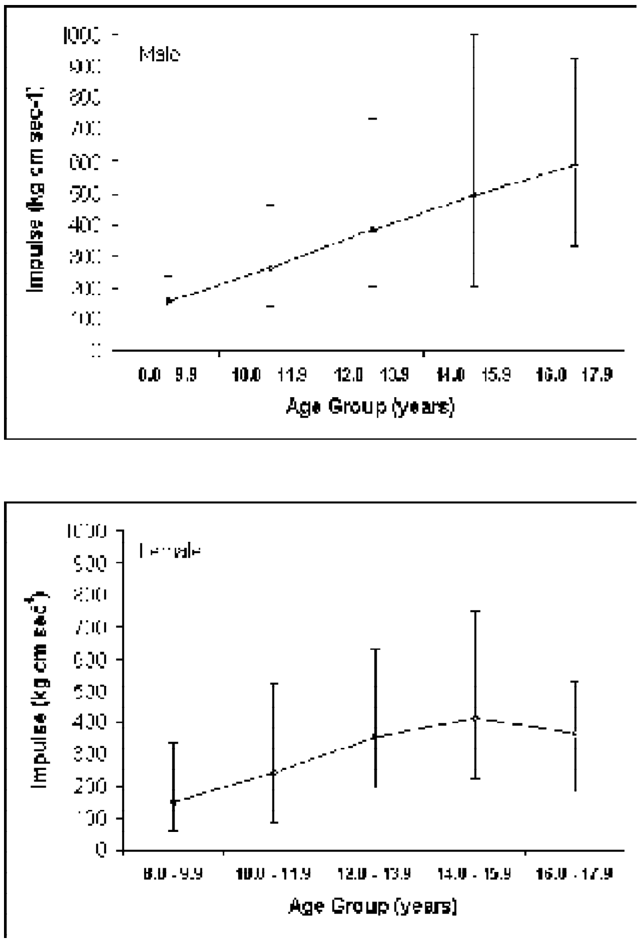

Figure 2 —Mean impulse and impulse range of normal age restricted categories for both males (a) and females (b).

vs. 1,722 N). In introducing body contact to this age group, the larger, early-maturation participants clearly gain a competitive advantage. In Britain, Baxter-Jones and Helms (1) found that male and female athletes in elite soccer, swimming, and tennis programs were of above average stature (indicating the pre-selection of early-maturation participants), with more than 50% of the athletes in soccer and tennis born in the first 3 months of the chronological age category and 70% in the first 6 months for soccer, tennis, and swimming. Similarly, Giacomini (14) and Dudink (9) have found significant numbers of elite level athletes to be born in the first 3 to 6 months of the year. The younger children in each age category are clearly disadvantaged. Basing competitive categories on chronological age clearly does a disservice to late maturing individuals and individuals born late in the chronological age category.

Table 4 The Percentage Agreement Between Normal Age Restricted and Impulse Categorization of the Combined Group, Male and Female Groupings

Age group (yrs)		Category 1 0 – 209 (kg cm sec^{-1})	Category 2 210 – 319 (kg cm sec^{-1})	Category 3 320 – 439 (kg cm sec^{-1})	Category 4 440 – 539 (kg cm sec^{-1})	Category 5 540 + (kg cm sec^{-1})
8.0–9.9	Combined	92.3	6.6	1.1	—	—
	Male	93.6	6.4	—	—	—
	Female	90.9	6.8	2.3	—	—
10.0–11.9	Combined	28.7	53.9	14.8	2.6	—
	Male	21.4	58.9	16.1	3.6	—
	Female	35.6	49.2	13.6	1.7	—
12.0–13.9	Combined	4.2	30.9	41.2	16.4	7.3
	Male	3.7	22.0	47.6	17.1	9.8
	Female	4.8	39.8	34.9	15.7	4.8
14.0–15.9	Combined	0.4	9.8	41.1	25.5	23.3
	Male	0.7	6.3	29.2	27.1	36.8
	Female	—	13.7	54.2	23.7	8.4
16.0–17.9	Combined	1.1	6.5	31.2	25.8	35.5
	Male	—	—	7.0	35.1	57.9
	Female	2.8	16.7	69.4	11.1	—

In order to take into account the large variation in structural and developmental factors at each chronological age and/or grade in school that would influence physical performance, early classification plans were developed based upon chronological age, height, body mass, and gender (8, 21, 24). Using a multiple regression analysis predicting athletic performance, these studies obtained multiple *R*s ranging from .40 to .67. However, more recent studies (cf. 2, 12) have concluded that motor fitness cannot be predicted from body size, chronological age, biological maturity, or their interactions.

While the studies of Espenschade (12) and Beunen et al. (2) would suggest that previous classification schemes may be based upon flawed assumptions, these studies have agreed that classification systems are important in order to maintain equitable groupings for the purpose of competition, increasing participation, and decreasing injuries. Problems inherent to age classification were addressed by the New York Department of Education, which funded a project entitled the Selection / Classification Program in 1973 that included a maturational assessment (16). Haffner (15) found that maturational-matched boys (based on genital assessment) between 12 and 19 years of age had significantly fewer injuries over a 1-year period. While 2% of the individuals matched on the basis of Tanner stages reported injury, in the same year as many as 50% of high school football players reported significant injury (15). It is common to find injury rates of 40% (31) to 82% (23) in youth sports in chronological-based sports programs.

For various reasons, it is clear that maturational assessment provides a better index of physical potential than chronological age and is the recommended method of classifying children in competitive sports (5, 15, 16, 22, 25). Sports participation based upon maturity assessment has been cited as reducing both the physiological and psychological "insult" of maturing athletes (5, 16, 25). However, while participation based upon maturational assessment appears to be the recommended practice, there is little or no evidence of this practice in today's literature. This may be due to the nature of maturity assessment, with an extreme cost incurred during skeletal age determination using x-rays or a need for individuals to disrobe during determination of Tanner stages (based on pubic hair and breast development). The present study presents an alternative to such practices.

The present study reports a classification system based upon simple, easily obtained anthropometric measurements, allowing it to be more easily adopted and administered by sport organizations. The underlying tenet of the present study is that classification schemes for youth sport have to be developed on factors beyond the individual's control, avoiding the use of body mass, while representing the individual's gross ability to generate force. In doing so, the present scheme would account for structural, functional, and performance advantages gained through early maturation in strength and power sports (5, 16, 30). The results obtained in the series of developed regression equations were as anticipated, from a theoretical standpoint, and accounted for gender differences in muscular development that occur during puberty (18, 20). To predict impulse in females, calf girth was selected by stepwise regression, while forearm girth was selected in males. This represents differences in development between males and females, with lower body dominance in muscular development in females and upper body dominance in muscular development in males.

The gender-specific equations developed in the present study (Eq. 1, Table 3) would account for 90% of the variance in impulse generated during a vertical jump trial in males and approximately 85% of the variance in impulse potential in females. However, due to the large technical error of measurement, and volitional control over measured flexed arm girth in males and chest girth in females, these equations are not recommended. To add a measure with no technical error of measurement, the second series of equations was developed that accounted for age (in decimal years). The rationale for this is that it represents an easily obtained, verifiable measure (birth certificate) that is of particular appeal to practitioners. The last equations (Eq. 3, Table 3) were developed to account for differences in muscle development within and across gender while using consistent measures in equations for both males and females. These regressions were restricted to entering height, age, calf girth, and forearm girth in both males and females, a procedure that did not limit the predictability of the equations (accounting for 88.5% and 85.6% of the variance in males and females, respectively).

To determine the degree to which age-restricted categories coincide with the impulse classification categories, the percentage of individuals in each age-restricted category that fell within each impulse classification category was examined (Table 4). If there were no systematic gender differences and no variability in maturation, one would expect 100% of the individuals to be properly classified, falling along the diagonal (within the shaded area). When examining a combined male and female grouping, the results demonstrate that the variability between age and impulse classification schemes is exaggerated within and beyond 12.0–13.9 years of age

(Table 4). This coincides with the mean peak height velocity, representing that period when variability in growth and progress toward mature adult form is greatest (20).

As the average female enters into the period of rapid growth, and reaches mature adult form sooner than males, it is also of interest to examine gender differences in the classification of youths for sport participation. In the present study, males and females demonstrate similar variability in impulse potential up to the age of 13.9 years, with similar proportions of the male and female samples being classified in each impulse category. However, as demonstrated in Figure 2, a plateau in performance in females develops between the ages of 12.0 and 13.9 years, with slight improvement until 15.9 years, while the impulse potential of males continues to increase throughout the age range (8.0–17.9 years). This phenomenon has been reported previously. For example, Espenschade (12), examining a compilation of cross-sectional data, reported a steady improvement in the performance of various physical tasks, among boys 10 to 18 years of age, and among girls up to the age of 13. More recently Branta et al. (4) reported mean performance of girls increased, on each of a variety of skills, from ages 8 to 14 years. Little and Day (17) suggest that physical performance factors were strongly associated with maturational status, mass, and lean muscle mass in perimenarcheal females.

Beyond the age of 14 years, many females will have reached mature adult form, with increases in sex specific fat deposition and less improvement in physical performance tasks. This is consistent with the present findings, demonstrating that the majority of females would not exceed an impulse classification of 3. Within the traditional age-restricted categorization of individuals for sport participation, this suggests that males and females should be allowed to compete together up to, and including, age 13.

The categorization of individuals according to their predicted impulse potential resolves many of the contentious issues within the traditional age-restricted categories. Individuals, regardless of age and gender, should be able to successfully compete in sport with those possessing a similar capacity to exert force. For this reason, using predicted impulse categorization methods, males and females of similar impulse potential should be able to compete together regardless of chronological age. While some may argue that there are social reasons that such a global integration of sport may not be acceptable, the classification scheme presented herein would be appropriate for activities that involve contact or strictly involve lower body activity and/or whole body movement.

Research demonstrates that a child's continued involvement in youth sport is linked to the perceived benefits of participation, including the opportunity for social interaction and the development of social relationships, enjoyment, and perceived competence (6, 10). Creating a competitive environment for children in which they feel competent will not only increase commitment to the sport (6) but have a significant impact on a child's self-esteem (10). The proposed classification system takes into account differences in physical maturity, helps equate performance, and allows children to feel competent in their competitive category; however, attention must be paid to an athlete's ability to interact with peers and develop friendships with people in similar peer groups (such as grade in school). As with any classification system, one must bear in mind individual variability, particularly that of extremely early- and late-maturing individuals, and the impact of classification on the child's psychosocial development.

In conclusion, the purpose of the present study was to devise a scheme for classifying children for competition and sport that is maturation-based. This was achieved through the use of an anthropometric prediction of impulse potential, thereby providing a method for classifying children into competitive categories up to the age of 14 years. Females of 14 years age and older might well be able to compete together in a single category, while males, with continued maturation and growth, should continue to be classified according to impulse potential up to the age of 18 years. At present, however, no evidence supports the generalization of the present equations to sports dominated by upper-body movement, such as baseball and tennis, in which striking force may be a more appropriate criterion than vertical jump when calculating impulse potential.

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