Title	Longitudinal development of physical fitness in Singapore children and adolescents
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LONGITUDINAL DEVELOPMENT OF PHYSICAL FITNESS IN SINGAPOREAN CHILDREN AND ADOLECENTS

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Up to 20% of curriculum time in physical education is devoted to physical fitness activities in Singapore schools. Results of fitness data collected in 1985-2003, among children and adolescents (Primary 4 - Junior College 2, N=236 female and N=218 male) show that longitudinal fitness development parallel physical changes in somatic growth (body mass and stature) in male and female youths with peak performance velocities of the majority of fitness attributes of male youths during Secondary 1-2 and in female youths during Primary 5-6. However, the highest values in physical fitness were attained in later years. These data mirror global physical fitness performance trends. Spearman rank correlations of physical fitness performance in male youths, with those attained in the year before and after the reference test years of Primary 5, Secondary 2, Secondary 4 and Junior College 2 were moderate-to-high (r=.29-.83, all $p<.05$), and were stronger in junior college and secondary school than in primary school. The equivalent rank correlations for body mass and stature were all >0.90. This implies than the stability of physical fitness performance increases with age, from childhood to adolescence and plausibly into early adulthood. Collectively, these data provide strong support that physical fitness tests in schools can be delimited to formal testing at Primary 5, Secondary 2, Secondary 3 and Junior College 2, rather than to test annually. This will free up time for other physical education activities for the holistic education of youths.

1 Introduction

Physical fitness is a state of well-being that comprises skill-related and health-related components. Skill-related physical fitness refers to an individual's athletic ability in sports such as tennis and encompasses skill-related attributes like dynamic balance, power, speed and agility; the health-related aspect is a measure of cardiovascular endurance, muscle strength, endurance, flexibility and body composition.

Physical fitness is measured by functional tests that are specific and usually normative-based, rather than criterion-based, thereby leaving unanswered as to how much of a specific fitness factor (e.g. muscular endurance) is required for a good quality of life (Chia *et al.*, 2007). The criterion-based standards are of course dependent on age, sex and functional occupation of the person (e.g. student or athlete).

Previous research by Quek *et al.* (1993), which analysed the cross-sectional data sample of 3 263 students aged 12-19 years, reported that over a 12-year period (1980-81 versus 1991-92), standing board jump, 4x10 m shuttle run improved at a rate of +0.25 % and +0.41 % per year, on the average while 2.4 km run performance declined at an average rate of -0.16 % per year. These Singaporean secular fitness trend over time, reflect a recent global trend analysis of paediatric fitness of more than 25 million youths, aged 6-19 years from 27 countries in Asia, North America, Europe, Australasia, Africa and the Middle East, over a 45-year period from 1958 to 2003, where results of field tests of aerobic performance declined -0.36 % per year with results of field tests of anaerobic performance remaining relatively unchanged (Tomkinson & Olds, 2007). Still, longitudinal data on physical fitness are more insightful and until now has not been elucidated for Singaporean youths.

The issues that surround annual testing of physical fitness among Singaporean youths - what basis is there for testing annually; what are the patterns of physical fitness growth curves; what are the implications of these growth curves; and how can these physical fitness test results help Singapore schools learn about the holistic development of youths through physical education - need to be addressed.

2 Materials and Methods

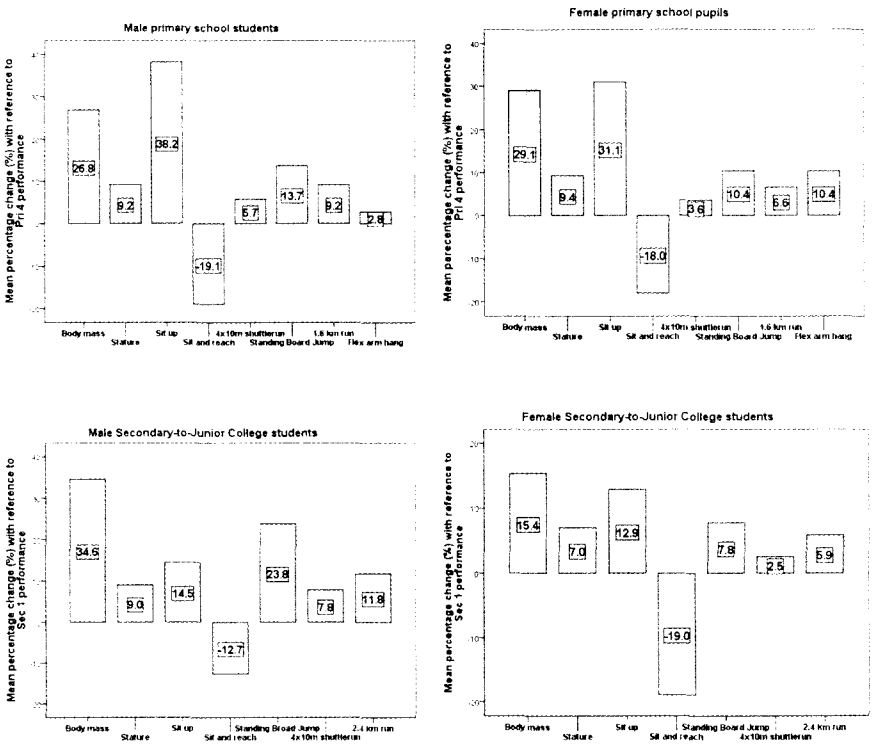
Subject. Physical fitness data (N=236 female and 218 male participants) were extracted from the Cockpit System of the Ministry of Education (tracked from primary, to secondary and to junior college in the years 1985-2003). The commencement age of tracking was 9 years and the terminal age of tracking was 18 years.

Physical Fitness Test Battery. In Singapore schools, the National Physical Fitness Awards (NAPFA) is a juxtaposition of health-related and skill-related aspects of physical fitness. They comprise the following tests: Height and body weight (these are compared to the norm-based ideal weight for height charts and classified accordingly as underweight, normal weight, and overweight); inclined-pull up time or 1 min pull up; 1 min sit-up, standing broad jump (better of two attempts); 4x10m shuttle run (better of two attempts); sit-and-reach (better of two attempts); a 1.6 (primary) or 2.4 km run (secondary/junior college). The tests were conducted by PE qualified teachers and/or were certified testers of the NAPFA.

Data Analysis. Changes in body mass, health and skill related physical fitness parameters, between years were computed. Spearman ranked correlation coefficients were computed to assess the relationship between performance in the referenced years, which were designated as primary 5 (age 9-10 yrs), secondary 2 (age 13-14 yrs), secondary 4 (age 15-16 yrs) and junior college 2 (17-18 yrs). The level of statistical significance was set a $p<0.05$. SPSS version 17.0 was used.

3 Results

The figures display percentage changes in body mass and stature in relation to percentage changes in physical fitness performance in primary pupils, and secondary to JC students.



The charts show that for primary school children, the greatest magnitude of change for was for sit up performance (31-38 %). Sit and reach performance declined by up to 19 % and 1.6 km run performance improved less than 11 %. This compares with a change in body mass and stature of 26.8-29.1 % and 9.0-9.4 %, respectively.

Primary 5 as reference test year	Primary 4 performance Spearman rank correlation (male/female)	Primary 6 performance Spearman rank correlation (male/female)
Body mass	.95/.93	.96/.94
Stature	.95/.95	.93/.92
1-min Sit Up	.57/.60	.68/.57
Standing Board Jump	.70/.66	.73/.77
4x10m Shuttle Run	.54/.47	.55/.52
Flex Arm Hang	.62/.53	.56/.48
Sit and Reach	.63/.78	.29/.30
1.6 km Run	.52/.47	.56/.64

All correlations are significant at $p<.05$.

Secondary 2 as reference test year	Secondary 1 performance Spearman rank correlation (male/female)	Secondary 3 performance Spearman rank correlation (male/female)
Body mass	.93/.92	.93/.92
Stature	.91/.92	.91/.95
1-min Sit Up	.62/.64	.60/.65
Standing Board Jump	.80/.77	.81/.81
4x10m Shuttle Run	.63/.60	.65/.63
Flex Arm Hang	.72/.72	.36/.41
Sit and Reach	.77/.82	.46/.44
2.4 km Run	.63/.59	.69/.66

All correlations are significant at $p<.05$.

Secondary 4 as reference test year	Secondary 3 performance Spearman rank correlation (male/female)	Junior college 1 performance Spearman rank correlation (male/female)
Body mass	.93/.94	.93/.93
Stature	.93/.96	.94/.95
1-min Sit Up	.61/.67	.51/.58
Standing Board Jump	.83/.82	.79/.79
4x10m Shuttle Run	.65/.66	.60/.65
Sit and Reach	.45/.47	.54/.63
2.4 km Run	.74/.70	.64/.61

All correlations are significant at $p<.05$.

Correlations for Pull Up and Flex Arm Hang are not computed because of differences in mode of assessment for the different age groups.

Junior college 2 as reference test year	Junior college 1 performance Spearman rank correlation (male/female)
Body mass	.92/.93
Stature	.95/.96
1-min Sit Up	.51/.62
Standing Board Jump	.80/.80
4x10m Shuttle Run	.63/.74
Pull up (male)/Flex Arm Hang (female)	.77/.75
Sit and Reach	.65/.72
2.4 km Run	.70/.69

All correlations are significant at $p<.05$.

For secondary-to-junior college adolescents, standing board jump improved 24 % in boys and sit up performance improved by 13 % in girls. Sit and reach performance continued to decline by up to 19 % in girls. 2.4 km run performance improved up to 12 % in boys. This compares with a change in body mass and stature of 15.4-34.6 % and 7.0-

9.0 %, respectively. Pull up and flex arm hang performance was omitted due to different methods of assessment for boys and girls and for different age cohorts.

To determine if the NAPFA test performances in the year before and after were significantly correlated with test performances taking the reference points of Primary 5, Secondary 2, Secondary 4 and JC 2, Spearman and Pearson correlations were run. These data are summarised in tabular form above.

4 Discussion

The development and training for physical fitness through various PE activities including fitness and conditioning constitute 10-20 % of the time spent during PE, and is increased developmentally as pupils progress from primary to secondary schools. However, physical fitness is only one dimension (physical) in the holistic development of youths that all schools in Singapore strive to achieve during the 10 years of compulsory schooling. The other components of holistic schooling in physical education include the cognitive (body of knowledge in PE and Sport), psychomotor (game skills) and affective domains (values inculcation). Time devoted to the development of the physical dimension should be strategic and evidence-based and appropriately apportioned to capitalise of the peak growth velocities (i.e. highest rate of change).

Results of the present study showed that in boys and girls, the peak growth velocities for most measures of physical fitness parallel that for somatic development (peak body mass and stature velocities) - for girls around Primary 5 and 6 (11-12 yrs) and for boys around Secondary 1 and 2 (13-14 yrs). For primary school children, sit up performance showed the greatest from primary 4 to primary 6 (31-38 %). Sit and reach performance declined by up to 19 % and 1.6 km run performance improved less than 11 %. For secondary-to-junior college adolescents, standing board jump improved 24 % in boys and sit up performance improved by 13 % in girls. Sit and reach performance continued to decline by up to 19 % in girls. 2.4 km run performance improved up to 12 % in boys. The present results are affirmed by other global studies of paediatric physical fitness where maturational effects (mirrored by changes in anthropometric characteristics) alone on physical fitness improvements on timed distance run in New Zealand children are documented (Tomkinson & Olds, 2007).

Emergent global epidemiological data show that physical fitness performance is relatively stable, compared to physical activity or sports participation and mirror the stability of body weight status over a 23-year period from adolescence to adulthood in138 female subjects (Matton *et al.*, 2007). This is also shown in the present study where Spearman rank order correlations, computed a year before and a year after the reference test years of Primary 5, Secondary 2, Secondary 4 and Junior College 2, for physical fitness performance, ranged from .29 to .78 for primary school pupils; .45 to .83 for secondary school students; and .51 to .80. The equivalent rank correlations for body mass and stature were all greater than .90. These results suggest that it is feasible and research-appropriate to delimit the testing of physical fitness to four times during the schooling

years- at Primary 5, Secondary 2, Secondary 4 and Junior College 2. This is because the short term stability of physical fitness performance is relatively high- .29 to .78 in primary school and .44 to .82 in secondary school and .51 to .80 in junior college.

In conclusion, physical fitness performance, especially in test items that involve the carriage of body mass suggest a strong association between changes in body mass with growth and maturation with changes in performance in the test item. As the short term stability of physical fitness is relatively strong, bi-annual testing of physical fitness is recommended as this will free up significant resources to be allocated to the enhancements in holistic development of children and adolescents through physical education (cognitive, psychomotor and affective domains)

5 Practical Applications

Limit physical fitness testing to 4 times in the schooling years - Primary 5, Secondary 2, Secondary 4 and Junior College 2. This will free up more time for the teaching and engagement of sports and games for the holistic development of youths during physical education classes.

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