

“Pattern As Reference”: windows of trainability among adolescents

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Abstract:

Introduction: Physical trainability among adolescents is crucial to optimize training and obtain best adaptations for physical performance, which is also related to anthropometric growth profiles. **Problem Statement:** Previous studies have shown different growth profiles inter-countries, hence this warrants more investigations on potential variance in patterns of windows of trainability. **Purpose:** The purpose of this study is to investigate how physical growth can be associated with and affected physical trainability among adolescents for training optimization purpose. **Materials & Methods:** A total of 800 students (400 boys and 400 girls) aged between 9 to 16 years participated in this study using fishbowl technique. Participants' weight and weight were measured and six physical fitness tests consisted of push-up (PU), bleep test (BLEEP), sit and reach (SnR), standing broad jump (SBJ), 30-meter sprint (SPRINT), and 10-meter shuttle run (SR) were tested. **Results & Discussions:** The results showed that peak growth seemed to occur around 13 and 14 years old for male students whereas 10 and 11 years old for female students. Peak of physical performance for male and female students aged 9 to 16 years old occurred before, during and after peak growth period, with both male and female students demonstrating their certain patterns. In overall, there was a significant relationship between physical growth and physical performance between 9 to 16 years old for both male and female students. **Conclusions:** The patterns obtained from this study could be used as a reference and guideline to plan physical training for adolescents, especially during PHV period where the peak of physical performance occurs for the windows of trainability for the long-term development. **Key Words:** Biological Maturation, Young Athletes, Physical Performance, Physical Training, Windows of Trainability

Introduction

When observing the growth process within an adolescents, puberty is a very important period. Among adolescents, a physical variables which are growth- and maturation- related from biological aspect need to be accounted in assessing and improving performance in sport. For instance, earlier maturation shows greater body height, body mass and muscle mass than those of the same chronological age who mature later (Armstrong and McManus, 2011). Body size, body shape, and body composition are key components of success in chronological age-group sport and most elite young athletes have physiques that promote their sport performance (Armstrong, 2013; Okun et al., 2020). Trainability is the adaptability of developing individuals to the training stimuli at different growth and maturation stages (Balyi et al., 2013), where there is a critical period of development that the stimulus can be timed to obtain best adaptation in regard to physical fitness.

While sport skills are trainable, the natural development is inevitable biological process (Malina et al., 2004). Every adolescent differs greatly from each other in terms of the rate at which they pass through the various phases of growth and maturation (timing and tempo). Height is among body dimensions that are typically utilized for growth monitoring in which with age, children are expected to become taller (Malina, 2014). Growth in height is known to have a distinct and measurable end point; however, adolescents differ greatly in the rate at which they pass through the various phases of growth and maturation. Due to such difference, peak height has been used, rather than chronological age, as indicator to characterize individual changes in body size and performance relative to the adolescent spurt in height (Malina et al., 2004; Philippaerts et al., 2006). Growth is discussed based on physical height since an increase (growth) in height can be easily observed (Wazir et al., 2012).

Sports are always associated with physical fitness. Without having a good physical fitness, is it difficult for an individual to perform in any sport excellently. Physical fitness consists of two components which are health-related (cardiorespiratory endurance, body composition, muscular strength, muscular endurance and flexibility) and skill-related (agility, balance, coordination, power, speed and reaction time) (Nieman, 2003). Physical fitness qualities have been associated with enhanced outcomes in physical activity, including sports participation and performance (Malina, 2014). Previous studies have shown that physical fitness could help

differentiates athletes with different levels of achievement such as those of elites and non-elites in certain sports (Pion et al., 2015, Norjali Wazir et al., 2019).

Instead of selection-and-deselection, adolescents should be oriented according to a specific sport based on their anthropometric measurements and physical performance tests for a chance to develop and hone their skills, and hence their future performance in sport (Norjli Wazir et al., 2017). Therefore, given the significance of biological maturation and its potential impact, these need to be highlighted during the developmental process (e.g., training) towards successful sport performance among adolescents (Ramli et al., 2020). Growth profile appears to be different inter-countries, possibly due to environmental, cultural, dietary and genetic factors. Hence, growth and height profiles of adolescents in Malaysia may differ from those in other countries (Wazir et al., 2012; Ramli et al., 2019). For example, Wazir et al. (2012) found that for young population in Malaysia, growth spurt of young male happened between age of 13 and 14 years old meanwhile for young female, it happened between 10 and 11 years old. This finding is partially consistent with what found in study by Malina et al. (2004), which highlighted that peak growth for young male occurred around 12 or 13 years old and young female around 10 or 11 years old.

Some studies on the relationship between peak height velocity (PHV) and physical performance among adolescents include work by Philippaerts et al. (2006) and Balyi et al. (2013). Philippaerts et al. (2013) did a longitudinal study on Flemish male youth soccer players and found the pattern where certain physical qualities showed peak performance at certain time during PHV period. Similar with finding by Balyi et al. (2013), they have found the optimal windows of trainability among adolescents based on five 5s (stamina, strength, speed, skill and suppleness). However, when their patterns were compared, variances in peak performance occurrence during PHV period (in young males) were seen in both, for example peak of strength and flexibility performances were found during PHV and after PHV respectively in work by Philippaerts et al. (2006) but same performances were found after PHV and before PHV respectively in work by Balyi et al. (2013). These differences may be attributed by the aforementioned factors as well as methodologies (e.g., physical tests) being used in these studies, and this calls for further work to gain more insight and information regarding the potentials of windows of trainability among adolescents. Therefore, the purpose of this study is to investigate the relationship between physical growth and physical performances among adolescents and to define in which phase (before/during/after peak growth) does their peak physical performances take place.

Material & Methods

A study population consists of male and female students aged between 9 to 16 years old in Malaysia. For the sampling purpose, all states in Malaysia were divided into 5 zones (Northern Zone, Central Zone, Southern Zone, Eastern Zone, and Eastern Malaysia Zone) that consists of several states correspondingly. A total of 800 students (400 boys and 400 girls) aged between 9 to 16 years have participated in this study using fishbowl technique. Tests and measurements were conducted to gather data on student anthropometry and physical performances. Height and weight measurements were used to indicate student's anthropometric measurements. Furthermore, the students were tested with six physical fitness tests to indicate their motor performance qualities which are muscular endurance, cardiorespiratory endurance, flexibility, power, speed and agility (Amri et al., 2014).

Correspondingly, the six physical tests are push-up (PU), bleep test (BLEEP), sit and reach (SnR), standing broad jump (SBJ), 30-meter sprint (SPRINT), and 10-meter shuttle run (SR). Sit and reach, standing broad jump, 30-meter sprint and 10-meter shuttle run are made based on the procedure by AAHPERD (1976). Bleep test's procedure is based on procedure made by Cooper Institute (1999). In addition, the VO₂max for bleep test used the method by Barnett et al. (1993). Subject height was measured using portable stadiometer. Body Composition Analyzer Tanita, TBF-300 was used to measure Weight and BMI of the subject. Data analysis was conducted using *Statistical Packages for The Social Sciences* (SPSS) for descriptive statistics and we converted the raw scores into standard scores (z-scores) to determine relationship between physical growth and physical performance using Pearson correlational analysis.

Results

Based on z-score analysis, in overall, there was a relationship between growth and physical performance for both male and female students. Based on Figure 1, the growth pattern showed that the height increase is directly proportional to the increase in age from 9 to 16 years old for both male and female students. In addition, peak growth seemed to occur around 13 and 14 years old for male students whereas 10 and 11 years old for female students. Peaks of their physical performance for both male and female students seemed to occur before, during and after their peak growth. There was also an increasing pattern of physical performance with physical growth for both male and female students.

Push-Up: Based on Figure 1 (upper left), in overall, increasing pattern in push-up performance for both male and female students were similar to increasing pattern in their physical growth (height). For male students, peak performances of push-up were observed before (between 9-10 and 11-12 years old) and after (between 15-16 years old) peak growth period whereas for female students, peak performance of push-up was observed after (between 11-12 year old) peak growth period.

Sit and Reach: Based on Figure 1 (upper right), in overall, increasing pattern in sit and reach performance for male students were similar to increasing pattern in their physical growth (height) whereas for female students, the pattern was not consistent where as they aged older, decline in the performance was observed. For male students, peak performance was observed after (between 15-16 years old) peak growth period. On the other hand, peak performance was observed before (between 9-10 years old) peak growth period for female students.

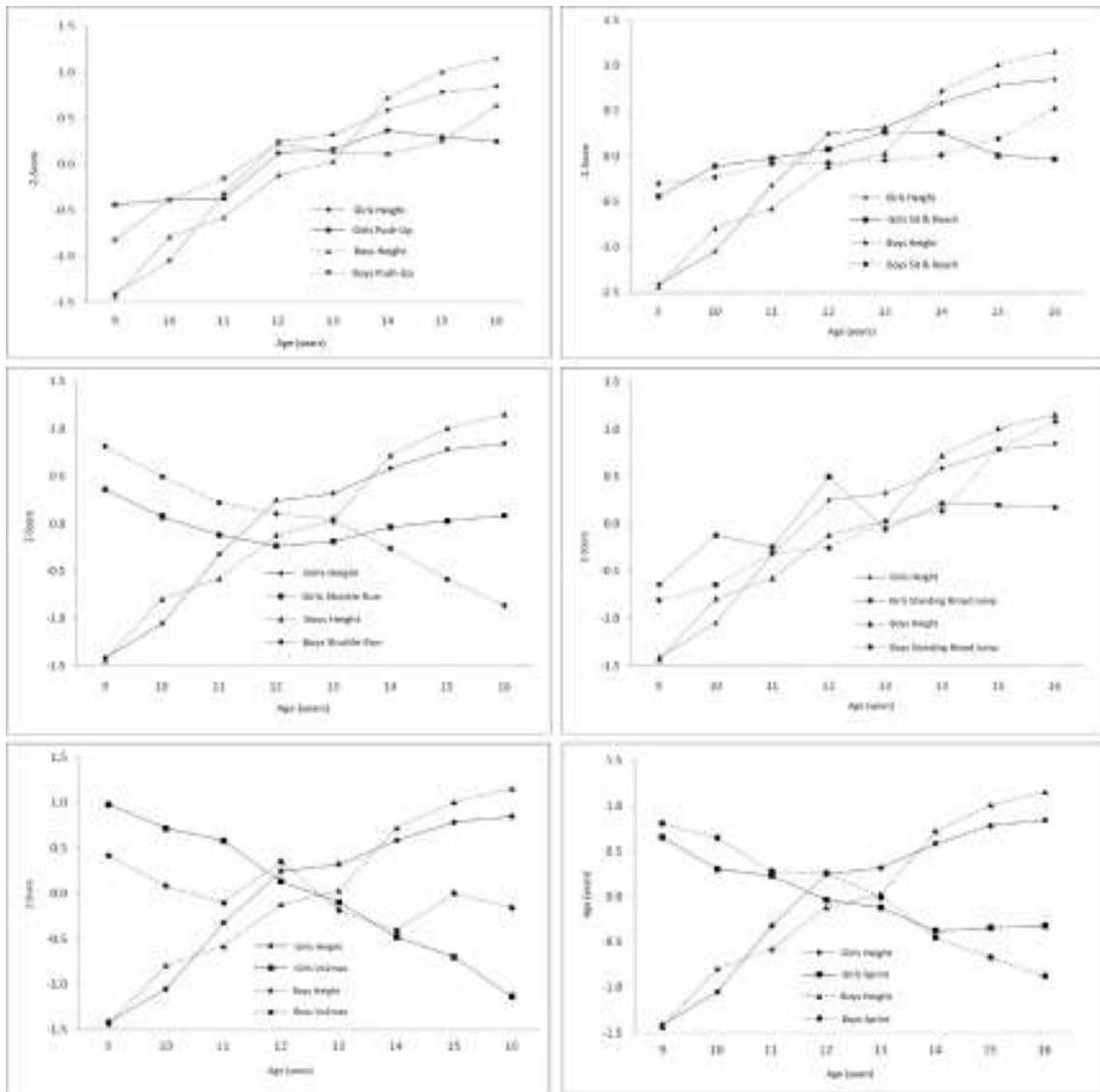


Fig.1: Physical performances based on height (Z-score) and age (Year) for push-up (upper left), sit and reach (upper right), 10m shuttle run (middle left), standing broad jump (middle right), 30m sprint (bottom right) and VO2max (bottom left).

10-meter Shuttle Run: Based on Figure 1 (middle left), in overall, increasing pattern in 10-meter shuttle run performance for male students were similar to increasing pattern in their physical growth (height) whereas for female students, the pattern was not consistent where as they aged older, decline in the performance was observed. For male students, peak performance was observed after (between 14-15 years old) peak growth period. In contrast, peak performance was observed before (between 9-10 years old) peak growth period for female students.

Standing Broad Jump: Based on Figure 1 (middle right), in overall, increasing pattern in standing broad jump performance for male students were similar to increasing pattern in their physical growth (height) whereas for female students, the pattern was not consistent where as they aged older, decline in the performance was observed. Peak performance was observed after peak growth period for both male (between 14-15 years old) and female students (between 11-12 years old).

30-meter Sprint Run: Based on Figure 1 (bottom right), in overall, increasing pattern in 30-meter sprint run performance for both male and female students were similar to increasing pattern in their physical growth

(height). For male students, peak performance was observed during (between 13-14 years old) peak growth period whereas for female students, peak performance was observed before (between 9-10 years old) peak growth period.

Bleep Test: Based on Figure 1 (bottom left), the pattern of VO₂max performance was not consistent with pattern of physical growth (height) for both male and female students. In general, as they aged older, decline in the performance was observed. For male students, peak performance was observed before (between 11-12 years old) peak growth period. For female students, best performance was observed at 9-years old group and consistently drop as ages older.

Pearson correlation analysis was used to determine relationship between physical growth (Height) and physical performances (PU, SnR, SR, SBJ, SPRINT, BLEEP) for both male and female students for each age group (9 to 16 years old). Table 1 displays the correlation analysis result based on age group. Based on Table 1, there was a significant relationship between physical growth and certain physical performance for age group of 10-years old, 13-years old and 16-years old for male students. For male student aged 10 years old, physical growth was significantly related to power (SBJ), speed (SPRINT), and cardiorespiratory endurance (BLEEP). For male student aged 13 years old, physical growth was significantly related to power (SBJ) only. For male student aged 16 years old, physical growth was significantly related to flexibility (SnR) only. Meanwhile for female students, there was a significant relationship between physical growth and certain physical performance for age group 9 years old and 15 years old. For female student aged 9 years old, physical growth was significantly related to cardiorespiratory endurance (BLEEP) only. For female student aged 15 years old, physical growth was significantly related to flexibility (SnR) only. But in overall, there was a significant relationship between physical growth and physical performance between 9 to 16 years old for both male and female students.

Table 1: Correlation analysis between physical growth and physical performance.

Test / Age	9	10	11	12	13	14	15	16	Overall (9-16)
<u>Male</u>									
PU	-0.10	0.16	-0.15	-0.22	0.18	-0.25	-0.27	-0.21	0.26**
SnR	-0.17	-0.21	-0.03	-0.05	-0.08	-0.01	-0.08	-0.39**	0.13*
SR	-0.01	0.26	0.03	-0.08	-0.26	0.10	0.05	0.11	-0.42**
SBJ	0.09	-0.34*	0.01	-0.16	0.39**	0.01	0.03	0.04	0.50**
SPRINT	-0.11	0.29*	0.01	-0.22	-0.15	-0.02	0.26	0.17	-0.48**
BLEEP	-0.06	-0.52**	-0.07	-0.26	0.04	-0.04	-0.24	-0.15	-0.22**
<u>Female</u>									
PU	-0.26	0.12	0.07	-0.05	-0.19	-0.22	-0.11	0.15	0.22**
SnR	-0.04	0.12	-0.02	-0.15	-0.15	0.11	0.30*	0.09	0.14**
SR	0.21	-0.06	-0.08	-0.05	-0.01	0.05	-0.08	-0.17	-0.09
SBJ	-0.09	0.02	-0.10	-0.05	0.06	0.03	0.17	0.20	0.22**
SPRINT	0.16	0.04	-0.04	0.01	-0.01	0.00	-0.13	-0.19	-0.27**
BLEEP	-0.35*	-0.06	-0.21	-0.01	0.07	-0.12	0.01	0.05	-0.55**

* $p < 0.05$ ** $p < 0.01$

NOTE: PU – Push-up (repetitions/minute); SnR – Sit & reach (cm); SR – 10-meter shuttle run (s); SBJ – Standing broad jump (cm); SPRINT – 30-meter sprint run (s); BLEEP – Bleep test (ml/kg/min).

Discussions

The focus of this study is to determine pattern of physical growth and physical performance among adolescents in Malaysia aged between 9 to 16 years old. Z-score correlation analysis showed there was a relationship between physical growth and physical performance for both male and female students. In overall, the pattern showed an improvement in all physical performance among male students as they grow older except for cardiorespiratory endurance (BLEEP) whereas all physical performance among female students seemed to decline as they grow older except for muscular endurance (PU). Pienaar and Viljoen (2010) have mentioned that strength and flexibility among males improve linearly with increment in age. Malina et al. (2004) have stated that speed for young males improves linearly with age from 5 to 17 years old. A study by Trudeau et al. (2003) have found out that push-up performance for females did not possessed significant relationship with physical growth.

Based on these findings, the peak of physical performance for male and female students aged 9 to 16 years old occurred before, during and after peak growth period (growth spurt). Table 2 shows a temporal information of when peak of physical performance occurs at what age period. Based on Table 2, for male

students, peak physical performance in terms of muscular endurance and cardiovascular endurance occurred before their PHV. Meanwhile, peak performance for speed occurred during their PHV and peak physical performance for the other physical performances which are flexibility, agility and power occurred after their PHV, including muscular endurance once again. For female students, peak performance for flexibility, agility, speed and cardiovascular endurance occurred before PHV. Meanwhile, peak performance for muscular endurance and power occurred after their PHV and there is no peak in physical performance occurs among female students during their PHV.

When certain physical qualities being compared with finding (pattern) from Balyi et al. (2013), some are consistent (such as strength and speed) and some are not consistent (such as cardiovascular endurance) with our finding. In addition, when compared with study on young males by Philippaerts et al. (2006), some findings are in agreement (such as flexibility and speed) with our findings. The uniqueness of each model can be due to other factors physically and biologically that may warrant further work. Interestingly, based on our finding (pattern), almost no (only speed performance among young males) peak performance occurred during PHV and this may be explained by the phenomenon described as "adolescent awkwardness". "Adolescent awkwardness" is the temporary performance declination due to disruption of motor coordination that caused by rapid increase in body size and proportion (growth spurt) during PHV, but the adolescents will eventually get used to it (Davies and Rose, 2000).

Table 2: Temporal information relating between peak growth period and peak physical performance.

Parameter	Peak physical performance Occurrence (BEFORE/DURING/AFTER PHV)	
	Male	Female
Physical Growth (Growth Spurt / PHV)	13-14 years old	10-11 years old
Push Up (muscular endurance)	BEFORE and AFTER (9-10; 11-12; 15-16 years old)	AFTER (11-12 years old)
Sit and Reach (flexibility)	AFTER (15-16 years old)	BEFORE (9-10 years old)
10m Shuttle Run (agility)	AFTER (14-15 years old)	BEFORE (9-10 years old)
Standing Broad Jump (power)	AFTER (14-15 years old)	AFTER (11-12 years old)
30m Sprint (speed)	DURING (13-14 years old)	BEFORE (9-10 years old)
Bleep Test (cardiovascular endurance)	BEFORE (11-12 years old)	Consistently drop as ages older.

Future recommendation from this study includes involving more physical testings that comprise all physical fitness components for more comprehensive work to better understand this physical growth potential impact on physical performance and sport performance holistically. Future work may also want to consider bigger sample size with wider age group variation, as well as other factors/variables that may influence physical growth, biological maturation and motor performance among adolescents.

Conclusion

Based on this study, the findings display the patterns of peak physical performance occurrence before, during and after PHV among male and female students aged between 9 to 16 years old. The patterns could be used as a reference and guideline to plan physical training for adolescents, especially those who undergoing puberty period. It is suggested that every specific components of fitness are being carefully emphasized and trained during PHV period, highlighting the importance of considering biological maturation factor on adolescents to optimize training and obtain best results (adaptations) from the training (windows of trainability).

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