THREE-YEAR EVOLUTION OF PHYSICAL FITNESS AND BMI IN SCHOOLCHILDREN AGED 12-16 YEARS WITH EXTREME BMI

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Abstract:

The aim of this study was to investigate a three-year development in BMI and physical fitness of schoolchildren aged 12-16 years with extreme weight status. *Taiwan Physical Fitness Test Battery*, assessing aerobic fitness (1600-meter walk/run test), power (standing long jump), muscular endurance (sit-up), and flexibility (sit-and-reach) in 16,945 boys, was implemented in September from the year 2006 till 2008. Overweight and underweight were defined by the baseline BMI data values that fall within the highest and lowest 5% of their age population, whereas the BMI data values that fall within one standard deviation of the mean was considered “normal” in this study. The results showed that BMI of schoolchildren in 2006 was ~2–3 kg/m^2 above the national average reported in 1993. All physical fitness components in the overweight group were substantially poorer than those in the normal group. Yet, these fitness parameters were improved over the three years in all groups. BMI in the underweight group increased at a faster rate than that in the normal and overweight groups. No difference was found in the jumping distance between the underweight and normal groups. Aerobic fitness in the underweight group was superior but flexibility and muscular endurance were slightly lower than those in the normal group. BMI of Taiwan schoolchildren increased substantially from 1993 to 2006 but leveled off from 2006 to 2008. Underweight schoolchildren during the growing period should not *a priori* be considered as physically weaker or unfit individuals.

Key words: *BMI, underweight, pediatric, childhood obesity, physical activity*

Introduction

Obesity in childhood increases the risk of being an obese adult (Dietz, 1994). In Taiwan, childhood obesity has increased significantly during the recent decades (Chu, 2005). In Britain, the prevalence of obesity is closely associated with a physically inactive lifestyle, yet total dietary consumption and a high-fat diet appear to be unrelated to the surge in the obese population (Prentice & Jebb, 1995; Willett & Leibel, 2002). Thus, increasing physical activity should be encouraged to prevent the worsening trend (Kopelman, 2000). Being physically fit is the ground for an individual to participate in physical activity, as one’s physical fitness status is associated with how comfortably a person can accommodate to physical challenges.

Underweight has also been regarded as an unfavorable health condition by some people, according to the reports showing a U-shaped relationship between mortality and BMI in adults (Wannamethee & Shaper, 1989). However, some adults may have initially a high weight status, leading to the development of metabolic disorders afterward (Kopelman, 2000), and resulting in debilitating weight loss and death. The reverse causation of an increased mortality among those with lower weights may be left unrecognized at the time of assessment (Lee, Manson, Hennekens, & Paffenbarger, 1993; Manson, et al., 1995). Weight loss within a short period of time during the clinical development of mortality-related conditions generally occurs in parallel with reduced physical fitness (Alley, et al., 2011;

Sato, Kodama, Sugawara, Saito, & Sone, 2009; Schaap, Pluijm, Deeg, & Visser, 2006). Therefore, longitudinal observations on both weight stability and physical fitness for an underweight population are required to clarify whether underweight should be regarded as an unfavorable condition in schoolchildren.

Very few studies reported a long-term observation on physical fitness in underweight boys in contrast to their normal and overweight peers. In a cross-sectional study, poor fitness against anaerobic physical activity for underweight adolescents has been documented (Bovet, Auguste, & Burdette, 2007). However, underweight girls tend to have higher muscular endurance (Artero, et al., 2010). Data for aerobic fitness (or cardiorespiratory fitness) in underweight boys are less available. In the current study, we performed a three-year longitudinal observation of BMI and physical fitness encompassing 4 dimensions in male schoolchildren aged between 12-16 years. The aim of the study was to determine whether underweight children (lowest 5% in BMI) are physically weaker than their age-matched normal and overweight peers (highest 5% in BMI) during a three-year growing period.

Methods and materials

Experimental procedure

The three-year trajectories of BMI and scores of the *Taiwan Physical Fitness Test Battery*, assessing aerobic fitness (1600-meter walk/run test), power (standing long jump), muscular endurance (sit-up), and flexibility (sit-and-reach), were determined in this cohort. To avoid the potential temperature effect of seasonal variations on the physical fitness test (Magal, Smith, Dyer, & Hoffman, 2009), information on test scores of the physical fitness battery and BMI across the entire nation was collected annually in September using onsite field tests. To protect the children's privacy, the names of the participants were transformed into digits before conducting any analysis. Students with disabilities were precluded from the study. Due to gender differences in physical fitness test components of the *Taiwan Physical Fitness Test Battery*, only boys were included for data analysis in the current study.

Subjects

This study was conducted as a part of the Taiwan Longitudinal Study of Fitness, Taiwan, Republic of China (ROC). Baseline measures of the participants (N=16,945 boys, 12–16 years, weight: 49.4±0.07 kg; height: 156.5±0.04 cm; BMI: 20.2±0.03 kg/m^2) were determined in September, 2006 (age levels: 12 years, n=2,036; 13 years, n=7,213; 14 years, n=3,730; 15 years, n=2,101; 16 years, n=1,865), and the follow-up data were collected in 2007 and 2008. Underweight was defined by the individuals with the baseline BMI that fall in the lowest 5% in their age group. The BMI data values that fall within one standard deviation of the mean were considered as "normal" weight in this study. In contrast, overweight represents the individuals with baseline BMI values in the top 5% of their age group. Informed consent was obtained from the legal guardians of all the subjects before investigation. This study was approved by the Institutional Review Board of the Ministry of Education, Taiwan, ROC.

Anthropometric measurements

Body mass index (BMI) was calculated from the ratio of weight/height^2 (kg/m^2). The values of height were recorded in meters to the nearest 1 mm. Body mass was measured to the nearest 0.1 kg with an electronic weight scale, with the subjects in school uniform.

Instruments

The *Taiwan Physical Fitness Test Battery* was performed according to the government guidelines indicated in the official website (http://www.fitness.org.tw/measure01.php) of the Ministry of Education, which includes four components: aerobic fitness (1600-meter walk/run test), power (standing long jump), muscular endurance (sit-up), and flexibility (sit-and-reach) detailed as follows.

Aerobic fitness. This component was assessed by a 1600-meter run/walk test. Each subject was encouraged to give their best effort to walk and/or run to complete the distance as fast as possible. This test was performed on a 400-meter track in the school. Trained staff counted the laps, motivated the schoolchildren during the assessment, and collected their data. The time required to complete the 1600-meter test was the outcome measure, which is a generally accepted method in reflecting aerobic (or cardiorespiratory) fitness (Castro-Pinero, Mora, Gonzalez-Montesinos, Sjostrom, & Ruiz, 2009).

Power. The standing long jump, representing explosive power, was performed as a two-foot take-off and landing with the best effort. The take-off was from a line on the floor. The subjects were free to use the countermovement with the arms and legs. The distance from the take-off to the point where the nearest heel touched the ground was the outcome measure. The best score from three attempts was recorded in centimeters (cm).

Muscular endurance. Subjects were lying down on their backs with the knees bent at a 90° angle with feet together. Another person held the ankles for stabilization. The heel was the only part of the foot that had to stay in contact with the ground. The fingers had to be interlocked behind the head. The backs of the hands were required to touch the ground at each movement. The sit-up started with a vocal command by the coach. The exercise commenced when the student began raising the upper body to the vertical position. The vertical position was defined as the base of the subject's neck being above the base of the spine. A repetition was not counted if the subjects failed to reach the vertical position, failed to keep their fingers interlocked behind their head, arched or bowed their back, raised their buttocks off the ground to raise their upper body, or let their knees exceed a 90° angle. Each subject had one minute to perform as many sit-ups as a best effort. The total number of sit-ups performed was the outcome measure of muscular endurance.

Flexibility. The standard sit-and-reach assessment was used to measure lower back and hamstring flexibility. A goniometer was used to measure the range of motion in the movements. The device displayed the distance when the device moved. Subjects sat on the floor, fixing their hip, back, and occipital region of the head to a wall, with legs held straight by a tester. They put both hands on the device, with arms held straight. In that position, zero point of the device was set. They were then asked to move forward as far as possible. The stretching distance was the outcome measure of flexibility.

Statistical analyses

Two-way ANOVA with repeated measures was used to determine the interactive and main effects of age and weight status for all variables over the three-year period. One-way analysis of variance (ANOVA) was further used to compare the mean difference of all the measured values among the underweight, normal and overweight groups each year. Tukey *post hoc* test, which holds the value of a type I error constant for each test, was utilized to distinguish the significant differences between the pairs of groups. A level of $p<.05$ was considered significant in all tests, and all values were expressed as means ± standard deviation (SD). A confidence interval (95% CI) was also used to present the magnitude of deviation of a mean of each variable.

Results

The average body weight of the cohort was ~8–10 kg greater than those of the schoolchildren investigated in 1993 by the Nutrition and Health Survey in Taiwan (Figure 1A). BMI of children in 2006 was ~2–3 kg/m^2 greater than that of the age-matched peers in 1993 (Figure 1B). Table 1 presents the three-year trajectories of BMI for schoolchildren

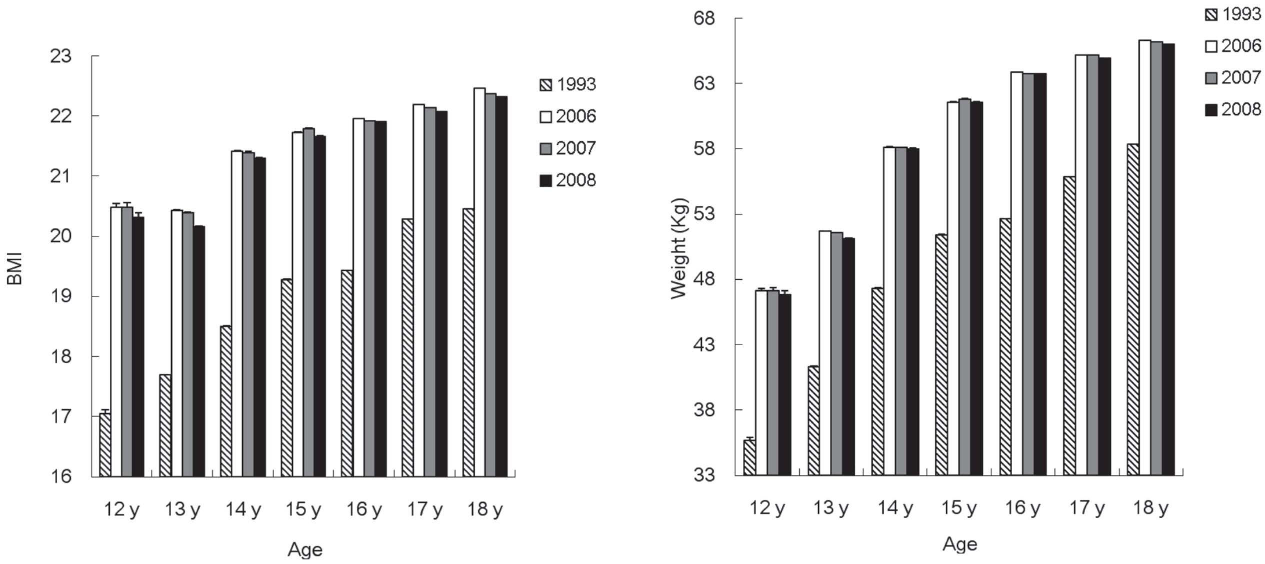

Figure 1. Average weight status of schoolchildren in 2006 – 2008 against the random data in 1993 from Nutrition and Health Survey in Taiwan

Table 1. BMI progression for schoolchildren with extreme weight

Unit	Underweight (n=848)		Normal (n=11,523)		Overweight (n=848)	
kg/cm	Mean±SD	CI	Mean±SD	CI	Mean±SD	CI
2006	15.2±0.73 [a]	15.1-15.3	20.2±2.32	20.9-21.0	31.3±2.54 [a]	31.2-31.5
2007	16.6±2.16 [a,b]	16.4-16.8	21.3±2.64	21.3-21.4	30.0±2.75 [a,b]	29.7-30.3
2008	17.2±2.41 [a,b]	17.0-17.4	21.6±4.42 [b]	21.6-21.7	29.8±4.90 [a,b]	29.4-30.1

[a] significance against the normal group, $p<.05$; [b] significance against baseline, $p<.05$.

who were underweight, normal, and overweight. BMI of underweight schoolchildren increased significantly over the three years, whereas BMI of overweight schoolchildren decreased significantly during the same period.

During the three years, the scores of the *Taiwan Physical Fitness Test Battery*, including the 1600-meter walk/run test (Table 2), standing long jump (Table 3), sit-up (Table 4), and sit-and-reach (Table 5), for both BMI extremes and the normal group improved significantly. Aerobic fitness in the overweight group was substantially lower than in the entire population across the three-year period, whereas the performance score in the underweight group was better than that in the normal group (Table 2). Standing long jump distance for the overweight group was significantly shorter than that for the normal group across the three-year period, whereas no significant difference was found between the underweight and the normal group (Table 3). Performance scores for one-minute sit-up test of both the underweight and overweight groups were slightly lower than that for the normal group (Table 4). A similar trend was observed in the score for sit-and-reach (Table 5).

Table 2. Aerobic fitness (1600-meter run/walk test)

Unit	Underweight (n=848)		Normal (n=11,523)		Overweight (n=848)	
Sec	Mean±SD	CI	Mean±SD	CI	Mean±SD	CI
2006	546.9±93.9 [a]	540.7-553.1	554.4±107.0	552.5-556.3	679.7±131.4 [a]	670.8-688.5
2007	542.4±106.3 [a]	535.5-549.2	548.5±106.6	546.6-550.4	668.5±131.1 [a]	659.5-677.5
2008	530.9±106.2 [a,b]	523.9-537.9	536.5±105.6 [b]	534.6-538.4	639.4±127.3 [a,b]	630.8-648.1

[a] significance against the normal group, p<.05; [b] significance against baseline, p<.05.

Table 3. Power (standing long jump)

Unit	Underweight (n=848)		Normal (n=11,523)		Overweight (n=848)	
cm	Mean±SD	95% CI	Mean±SD	95% CI	Mean±SD	95% CI
2006	184.4±24.4	182.6-186.2	189.4±30.7	188.8-189.9	160.0±29.0 [a]	158.1-162.0
2007	195.7±25.7 [b]	193.9-197.5	199.8±30.2 [b]	199.2-200.3	170.2±29.6 [a,b]	168.2-172.2
2008	205.6±26.3 [b]	203.7-207.4	208.3±29.2 [b]	207.7-208.8	179.1±29.1 [a,b]	177.1-181.1

[a] significance against the normal group, p<.05; [b] significance against baseline, p<.05.

Table 4. Muscular endurance (sit-up)

Unit	Underweight (n=848)		Normal (n=11,523)		Overweight (n=848)	
Times/min	Mean±SD	95% CI	Mean±SD	95% CI	Mean±SD	95% CI
2006	35.8±9.0 [a]	35.2-36.4	38.1±9.5	37.9-38.3	30.0±9.4 [a]	29.4-30.6
2007	38.4±9.2 [b]	37.8-39.0	40.4±9.4 [b]	40.3-40.6	32.8±9.3 [a,b]	32.1-33.4
2008	40.1±9.1 [a,b]	39.6-40.7	42.0±9.4 [b]	41.9-42.2	34.9±9.8 [a,b]	34.3-35.5

[a] significance against the normal group, p<.05; [b] significance against baseline, p<.05.

Table 5. Flexibility (sit-and-reach)

Unit	Underweight (n=848)		Normal (n=11,523)		Overweight (n=848)	
cm	Mean±SD	95% CI	Mean±SD	95% CI	Mean±SD	95% CI
2006	24.6±8.3 [a]	24.0-25.1	26.7±9.1	26.6-26.9	25.5±9.1 [a]	24.9-26.1
2007	25.0±9.0 [a]	24.4-25.6	27.4±9.6	27.3-27.6	26.4±9.4 [a]	25.7-27.0
2008	25.5±9.5 [a]	24.9-26.2	27.9±10 [b]	26.1-29.7	26.6±9.2 [a,b]	26.0-27.2

[a] significance against the normal group, p<.05; [b] significance against baseline, p<.05.

Discussion and conclusions

Underweight is generally thought of as an unfavorable condition in adults, according to the report showing a U-shaped relationship between BMI and mortality (Wannamethee & Shaper, 1989). Occasionally, being underweight in children could be due to the result of a debilitating illness or malnutrition, which could cause impaired physical fitness. However, we found that underweight schoolchildren exhibited faster progression in BMI increase, better aerobic fitness, with only slightly lower muscular endurance and flexibility than normal age-matched peers, suggesting that they should not *a priori* be considered physically weaker or unfit compared to their normal peers. The onset of a growth spurt during maturation can also affect both BMI and physical fitness due to a disproportional change in muscle-bone growth (Harris, Perreira, & Lee, 2009). In the normal group, overall physical fitness and BMI increased during the three-year growth. Therefore, we speculate that the faster rate of BMI increase in the underweight group than those in the normal and overweight groups may partly reflect the individual variations of children in their timetable of growth spurt.

Aerobic fitness is markedly impaired in the overweight group compared to the normal group. This result is somewhat similar to a cross-sectional study investigating 27 junior females, which shows declines in oxygen consumption and treadmill running as fatness increases (Rowland, 1991). Low aerobic fitness in the high BMI extremes could be due to the inert load created by extra body fat. Additionally, obesity is known as an important risk factor for predicting respiratory disturbances (Ng, et al., 2004). These physiological or anatomical characteristics are expected to limit the obese children participating in aerobic exercise, which can subsequently result in a vicious cycle of chronic accumulation of body fat and a less active lifestyle. On the contrary, absence in the aforementioned thoracic limitation and weight burden might underlie the fact that underweight adolescents had better aerobic fitness than their normal and overweight peers.

Due to the differences in age range and testing methods, not all studies produce the same result in a physical fitness profile for children with extreme BMI. For example, both underweight and normal children have been reported to have significantly higher performance in the lower-body explosive strength tests than their overweight counterparts. However, impaired muscular strength performance in underweight children aged between 6 to 17.9 years (1,513 boys and 1,265 girls) was not found in this previous study (Castro-Piñero, et al., 2009). Impaired physical fitness in overweight children is more consistently observed among the studies. With a random sample of 1,068 schoolchildren (7-12 years old) in Spain, overweight children had lower performances in all tests requiring propulsion or lifting of the body mass (standing broad jump, sit-ups, bent-arm hangs, speed shuttle run and endurance shuttle run) compared with their normal weight counterparts (Casajús, Leiva, Villarroya, Legaz, & Moreno, 2007). Furthermore, the results of our study are partially different from the cross-sectional study performed in the Republic of Seychelles (Bovet, et al., 2007). They found an inverse J-shape relationship between BMI and fitness score for 7 of the 9 tests. However, all tests reported in their study were more anaerobic in nature. It is currently known that athletes in different disciplines may be characterized by different weight status (Chen et al., 2009).

The present study shows a small improvement in flexibility during the three-year growth period. However, the length of observation and ethnic variation can also lead to different outcomes. Micheli, Stratford, Tarnopolsky, and Lotter, (2000) investigated 948 high school students in a trunk flexibility test. They found a slight decrease in flexibility of the quadriceps muscle over a six-month period. Furthermore, trunk flexibility was found to decrease markedly in a randomly selected group consisting of 220 boys aged 16 years and reinvestigated 18 years later (Barnekow-Bergkvist, Hedberg, Janlert, & Jansson, 1996). This study may have observed the aging effect instead of maturation. Flexibility is determined by elastic tissues component, including skeletal muscle, blood vessel, and connective tissue in the fascia, ligaments, and tendon (Gillette & Fell, 1996; Yamamoto, et al., 2009), which can be largely affected by secondary aging.

We must also note that weak physical fitness represents a major limitation for sport participation. The result of the present study suggests that overweight, but not underweight, remains a major concern for schoolchildren. Increasing physical activity is an important intervention in the prevention and treatment of childhood obesity (Chrystalleni, Demosthenes, & Antonia-Leda, 2009; German, et al., 2008; Oliver, et al., 2010). Yet, to improve adherence of obese schoolchildren to a sport or exercise program is generally considered as a challenging task (Eisenmann, Wickel, Welk, & Blair, 2005). For those overweight children, weight reduction by reducing nutrient intake can be placed in the initial phase of a weight control program. However, body mass rebound usually occurs after 6 months when only dietary control is administered (Mingfang & Bernard, 2009). Physical activity should gradually increase following the early phase of weight reduction.

The major limitation of the study is that BMI is not an obese marker, which only reflects weight status. Children grow at different rates. A study based on body fatness will provide a better physiological parameter to determine whether a particular person demands closer attention in weight control. Another limitation of the study is that the baseline physical activity of these schoolchildren was not recorded, which leaves the causal association between BMI and physical fitness unrecognized.

The present study documents the Taiwan population data in 2006 that BMI of schoolchildren substantially increased by ~2–3 kg/m^2 and body weight increased by ~8–10 kg compared to the random data collected in 1993. It should be noted that this dramatic surge in body weight occurred in a fairly short period of time. However, unlike most of the other industrialized nations, this trend leveled off from 2006 to 2008. Furthermore, our data do not support the notion that underweight schoolchildren should *a priori* be considered physically weaker or unfit compared to their age-matched peers.

References

Alley, D.E., Metter, E.J., Griswold, M.E., Harris, T.B., Simonsick, E.M., Longo, D.L., et al. (2011). Changes in weight at the end of life: Characterizing weight loss by time to death in a cohort study of older men. *American Journal of Epidemiology*, *172*(5), 558-565.

Artero, E.G., España-Romero, V., Ortega, F.B., Jiménez-Pavón, D., Ruiz, J.R., Vicente-Rodríguez, G., et al. (2010). Health-related fitness in adolescents: underweight, and not only overweight, as an influencing factor. The AVENA study. *Scandinavian Journal of Medicine & Science in Sports*, *20*(3), 418-427.

Barnekow-Bergkvist, M., Hedberg, G., Janlert, U., & Jansson, E. (1996). Development of muscular endurance and strength from adolescence to adulthood and level of physical capacity in men and women at the age of 34 years. *Scandinavian Journal of Medicine & Science in Sports*, *6*, 145-155.

Bovet, P., Auguste, R., & Burdette, H. (2007). Strong inverse association between physical fitness and overweight in adolescents: A large school-based survey. *International Journal of Behavioral Nutrition and Physical Activity*, *4*(1), 24.

Casajús, J.A., Leiva, M.T., Villarroya, A., Legaz, A., & Moreno, L.A. (2007). Physical performance and school physical education in overweight Spanish children. *Annals of Nutrition and Metabolism*, *51*, 288-296.

Castro-Piñero, J., González-Montesinos, J.L., Mora, J., Keating, X.D., Girela-Rejón, M.J., Sjöström, M., & Ruiz, J.R. (2009). Percentile values for muscular strength field tests in children aged 6 to 17 years: Influence of weight status. *Journal of Strength & Conditioning Research*, *23*, 2295-2310.

Castro-Pinero, J., Mora, J., Gonzalez-Montesinos, L., Sjostrom, M., & Ruiz, J.R. (2009). Criterion-related validity of the one-mile run/walk test in children aged 8-17 years. *Journal of Sports Sciences*, *27*(4), 405-413.

Chen, Y.L., Huang, C.Y., Lee, S.D., Chou, S.W., Hsieh, P.S., Hsieh, C.C., et al. (2009). Discipline-specific insulin sensitivity in athletes. *Nutrition*, *25*(11), 1137-1142.

Chrystalleni, L., Demosthenes, B.P., & Antonia-Leda, M. (2009). Physical activity mediates the protective effect of the Mediterranean diet on children's obesity status: The CYKIDS study. *Nutrition*, *26*(1), 61-67.

Chu, N.F. (2005). Prevalence of obesity in Taiwan. *Obesity Reviews*, *6*(4), 271-274.

Dietz, W.H. (1994). Critical periods in childhood for the development of obesity. *American Journal of Clinical Nutritrion*, *59*(5), 955-959.

Eisenmann, J.C., Wickel, E.E., Welk, G.J., & Blair, S.N. (2005). Relationship between adolescent fitness and fatness and cardiovascular disease risk factors in adulthood: The Aerobics Center Longitudinal Study (ACLS). *American Heart Journal*, *149*(1), 46-53.

German, V., Rey-López, J., Miguel, M., Luis, A.M., Julia, W., Carlos, R., et al. (2008). Television watching, videogames, and excess of body fat in Spanish adolescents: The AVENA study. *Nutrition*, *24*(7), 654-662.

Gillette, P.D., & Fell, R.D. (1996). Passive tension in rat hindlimb during suspension unloading and recovery: Muscle/joint contributions. *Journal of Applied Physiology*, *81*(2), 724-730.

Harris, K.M., Perreira, K.M., & Lee, D. (2009). Obesity in the transition to adulthood: Predictions across race/ethnicity, immigrant generation, and sex. *Archives of Pediatrics & Adolescent Medicine*, *163*, 1022-1028.

Kopelman, P.G. (2000). Obesity as a medical problem. *Nature*, *404*(6778), 635-643.

Lee, I.M., Manson, J.E., Hennekens, C.H., & Paffenbarger, R.S. (1993). Body weight and mortality. A 27-year follow-up of middle-aged men. *Journal of the American Medical Association*, *270*, 2823-2828.

Magal, M., Smith, R.T., Dyer, J.J., & Hoffman, J.R. (2009). Seasonal variation in physical performance-related variables in male NCAA division III soccer players. *Journal of Strength & Conditioning Research*, *23*(9), 2555-2559.

Manson, J.E., Willett, W.C., Stampfer, M.J., Colditz, G.A., Hunter, D.J., Hankinson, S.E., et al. (1995). Body weight and mortality among women. *New England Journal of Medicine*, *333*(11), 677-685.

Micheli, L.J., Stratford, P.W., Tarnopolsky, M., & Lotter, A. (2000). Is adolescent growth associated with changes in flexibility? *Clinical Journal of Sport Medicine*, *10*, 76.

Mingfang, L., & Bernard, M.Y.C. (2009). Pharmacotherapy for obesity. *British Journal of Clinical Pharmacology*, *68*(6), 804-810.

Ng, D.K., Lam, Y.Y., Chan, C.H., Cheng, T.O., Woo, K.S., Chook, P., et al. (2004). Dietary intervention combined with exercise improves vascular dysfunction but also obstructive sleep apnea in obese children. *Circulation*, *110*(12), e314.

Oliver, S.R., Rosa, J.S., Minh, T.D.C., Pontello, A.M., Flores, R.L., Barnett, M., et al. (2010). Dose-dependent relationship between severity of pediatric obesity and blunting of the growth hormone response to exercise. *Journal of Applied Physiology*, *108*(1), 21-27.

Prentice, A.M., & Jebb, S.A. (1995). Obesity in Britain: gluttony or sloth? *British Medical Journal*, *311*(7002), 437-439.

Rowland, T.W. (1991). Effects of obesity on aerobic fitness in adolescent females. *American Journal of Diseases of Children*, *145*, 764-768.

Sato, M., Kodama, S., Sugawara, A., Saito, K., & Sone, H. (2009). Physical fitness during adolescence and adult mortality. *Epidemiology*, *20*(3), 463-464.

Schaap, L.A., Pluijm, S.M.F., Deeg, D.J.H., & Visser, M. (2006). Inflammatory markers and loss of muscle mass (sarcopenia) and strength. *American Journal of Medicine*, *119*(6), 526.e529-526.e517.

Wannamethee, G., & Shaper, A.G. (1989). Body weight and mortality in middle aged British men: Impact of smoking. *British Medical Journal*, *299*, 1497-1502.

Willett, W.C., & Leibel, R.L. (2002). Dietary fat is not a major determinant of body fat. *American Journal of Medicine*, *113*(9, Supplement 2), 47-59.

Yamamoto, K., Kawano, H., Gando, Y., Iemitsu, M., Murakami, H., Sanada, K., et al. (2009). Poor trunk flexibility is associated with arterial stiffening. *American Journal of Physiology*, *297*(4), H1314-1318.

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TROGODIŠNJI TREND PROMJENA TJELESNE PRIPREMLJENOSTI I INDEKSA TJELESNE MASE U UČENIKA U DOBI OD 12 DO 16 GODINA S EKSTREMNIM INDEKSIMA TJELESNE MASE

Cilj je ovog istraživanja bio ustanoviti trogodišnji trend razvoja indeksa tjelesne mase (ITM) i tjelesne pripremljenosti u učenika, u dobi između 12 i 16 godina, s ekstremnim vrijednostima tjelesne težine. Tajvanski sklop testova za tjelesnu pripremljenosti (*Taiwan Physical Fitness Test Battery*), koja uključuje procjenu aerobne pripremljenosti (test hodanja/trčanja na 1600 metara), eksplozivne snage (skok u dalj s mjesta), mišićne izdržljivosti (podizanje trupa iz ležanja na leđima) i fleksibilnosti (sjed-i-dohvat), primijenjen je od 2006 do 2008 godine u mjesecu rujnu na uzorku od 16.945 dječaka. Preteški (*overweight*) i prelagani (*underweight*) ispitanici bili su definirani prema inicijalnoj vrijednosti ITM-a za dobnu skupinu populacije ispitanika kao oni koji se ubrajaju među 5% s najvišim odnosno najnižim vrijednostima ITM. Ispitanici koji su se nalazili unutar jedne standardne devijacije smatrali su se „normalnima“. Rezultati su pokazali da je ITM tajvanskih učenika u 2006. godini bio za ~2–3kg/m^2 veći od nacionalnog prosjeka objavljenog 1993. godine. Sve varijable tjelesne pripremljenosti u grupi prekomjerno teških bile su značajno lošije u odnosu na rezultate koje su postigli ispitanici u normalnoj grupi. Ipak, rezultati su se u svim mjerenim varijablama u svim grupama poboljšali tijekom 3 godine mjerenja. ITM je u grupi nedovoljno teških porastao većom brzinom nego u grupama normalnih i prekomjerno teških učenika. Nije utvrđena značajna razlika u rezultatima skoka u dalj s mjesta između grupa nedovoljno teških i normalnih ispitanika. Nedovoljno teški ispitanici imali su najbolje rezultate u aerobnoj izdržljivosti u odnosu na ostale grupe, dok su u fleksibilnosti i mišićnoj izdržljivosti bili nešto slabiji nego ispitanici u normalnoj grupi. ITM je u tajvanske djece značajno porastao u razdoblju od 1993. do 2006. godine, ali je i stagnirao u razdoblju od 2006. do 2008. godine. Nedovoljno teška djeca ne bi se smjela *a priori* smatrati fizički slabijom ili nespremnom tijekom perioda odrastanja.

Ključne riječi: *ITM, nedovoljno teški, pedijatrijski, pretilost u djetinjstvu, tjelesna aktivnost*