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Physical Fitness: A Proxy for Long-term Health Risks in Thai Adults

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Abstract

Objective: the lack of physical activity (PA) and physical fitness (PF) are leading causes of obesity, diabetes, and coronary heart disease. This cross-sectional study measured PA and PF levels in young male adults to determine associations with body mass index (BMI) and waist circumference (WC). The null hypothesis was that there would be no differences in the associations, meaning neither PA nor PF identified those at risk.

Material and methods: the short form of the International Physical Activity Questionnaire was used to investigate PA levels of 624 Thai male undergraduates attending compulsory physical education courses at an international college. Height and weight were measured to determine BMI, and WC was measured to determine abdominal obesity. Three test items–standing broad jump, 4x10m shuttle run, sit-ups–were conducted to assess PF.

Results: 22% failed to reach the minimum threshold of 150 minutes per week of moderate PA as recommended by the World Health Organization. Using Asian BMI criteria, 16.7% were overweight and 25.2% were obese. PF levels were modest. Obesity was more likely in the physically inactive and the physically unfit. Additionally, PF was a better indicator than self-reported PA at identifying those at risk.

Conclusion: this cohort is sedentary in its PA habits, overweight, and comparatively physically unfit. These findings have long-term health implications. PF was better at identifying those at risk and as a proxy for future ill health may have diagnostic benefits in preliminary risk assessment.

Keywords: Asia, Energy Expenditure, Exercise, Fitness, Obesity

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Physical inactivity is a leading risk factor in global mortality rates accounting for 6% of annual deaths worldwide.[1] As a preventative measure, the World Health Organization (WHO) recommends that those aged 18-64 do a minimum of 150 min/week of moderate physical activity (PA), or its equivalent.[2] Despite these recommendations, PA has been in decline globally[3] and young Asian adults have lower PA rates than those in other regions.[4,5] The world-wide decline in PA is matched by a world-wide rise in obesity which doubled over the two decades straddling the new millennium, including in Thailand.[6] Obesity in Thailand is more pronounced in urban rather than rural communities. It is the scourge of well-off urbanites.[7]

There are gender differences. Young males are more prone to obesity than young females. In 2016, 74 million boys worldwide were obese compared to 50 million girls.[9] There are regional differences too. In high-income countries, BMI has plateaued, albeit it at high levels, but is accelerating in Southeast Asia for boys.[8]

Like PA, obesity is linked to rising mortality rates. It is also a risk factor for Type 2 Diabetes Mellitus (T2DM) whose rates in Thailand for children and adolescents tripled between 1986 and 1997.[9] Obesity is also a risk factor for the metabolic syndrome (MetS) which is associated with all-cause mortality.[10] Globally, the incidence of MetS in obese children is 29.2%.[11] For Thai adult males, MetS is higher in urban than rural areas.[12]

PA is an effective antidote to obesity, and surveys are a standard instrument for measuring PA. However, though easy to use, respondents may not recall their PA levels accurately. They may also differ in how they interpret the PA categories. Alternatives are pedometers and accelerators, but these are expensive and time-consuming to use.
A more viable option are physical fitness (PF) tests. These can be conducted in a single session with minimal equipment. PF has pedigree in identifying those at risk[13,14], but there is little evidence from PF tests in Thailand.

In this study, the use of objectively measured PF tests was trialed and the results compared with a PA survey completed by the same participants. If PF tests are more effective than PA surveys at identifying those at risk, they could become part of the toolkit for health risk assessment.

Research Questions (RQs)

RQ1: Does PF have stronger associations with obesity than PA?

RQ2: Are the PA levels of this cohort a concern?

RQ3: Are the BMI rates of this cohort a concern?

RQ4: Are the WC rates of this cohort a concern?

RQ5: Are the PF levels of this cohort a concern?

Material and Methods

Thai male undergraduates attending Health and Physical Education (HPE) classes were recruited to participate in the study [part of a larger study approved by Mahidol University Committee for Research Ethics (Social Sciences):2015/089 (B2)]. They all signed informed consent forms. As these classes were compulsory, those recruited were representative of the 1500 male students at the college. 693 students aged 16-24 (mean:19.94; SD=1.71) were recruited but this was reduced to 624 when incomplete forms and outliers were removed. Thus, data from 40-45% of the total Thai male college population were collected. Sample size was estimated using the table in Bartlett et al (2001).[15] The confidence interval was set at 95% and the confidence level (margin of error) at 5%. Using categorical data, for a population of 1,500, the sample size should be at least 461. This study had 624 participants–a sufficient sample size.

The test protocol was completed in the first HPE lesson in 46 classes between September 2015 and May 2016. Participants completed a self-report PA questionnaire, had several body measurements taken–height, weight, WC–and completed three fitness tests: standing broad jump (SBJ); 4x10m shuttle run (SR); sit-ups (SU). Digital medical scales, with a built-in height rod, and calibrated beforehand, measured weight and height. Participants wore shorts and singlet, but no shoes. WC was measured using the same standard, non-stretch tailor’s measuring tape across classes.

PA Questionnaire

The short form of the International Physical Activity Questionnaire (IPAQ) was used as it is a standardized test for making comparisons worldwide for 18 to 65-year-olds. Its reliability and validity have been confirmed by several studies.[16,17]

IPAQ asks participants to differentiate between four levels of PA: vigorous (causing participants to "breathe much harder than normal"); moderate (causing participants to "breathe somewhat harder than normal"); walking; sitting.[18] The first three are reported on here.

Participants were briefed on IPAQ definitions for PA intensity levels and asked to report on two aspects of each level: how often "in the last 7 days" the participant had engaged in that level; for how long they had engaged at that PA level on any given day. The questionnaire [Appendix 1], was prefaced with a demographics section, translated into Thai [Appendix 2], and given to participants to complete anonymously.

PF test items

Selected PF test items would depend on whether the goal was a criterion-based or a norm-based approach. Criterion-based items are selected for their correlation with job fitness. For example, Rhea et al (2004) identified a set of test items for firefighters which correlated best with the performance criteria of actual firefighting: items included bench press and 400m sprint.[19] In contrast, norm-based test items are selected to measure health-related fitness. An example is the 'Québec en Forme' Project in Canada which aims to measure children's (0-17 years) PF so as to make early interventions to prevent obesity.[13] This study took a norm-based approach.

From the literature, three test items stood out. SBJ was used in eight studies and SU in seven.[20,21] SBJ is also used in the ALPHA test suites where Ruiz et al. (2010) reported that it is a good indicator of overall muscle strength.[22] Both items can be found in the AAPHER fitness tests. Ortega et al. (2008) also reported on the reliability of the two tests in the HELENA Study.[23] The third test item was SR which was used in five studies, including Deforche et al. (2003), and usually in the 4x10m format (three studies).[14] Two studies mirrored our own choices and used all three items.[13,14]

A PF Index was determined from a composite of the three PF test items to see if the sum of the whole was greater than the sum of the individual parts. How are composites determined? Using data from the Aerobics Centre Longitudinal Study, Ruiz et al. (2008) investigated the association between muscular strength and all-cause mortality.[24] Their composite combined the standardized values of bench and leg presses which were determined by taking an individual's score and subtracting the mean, and then dividing by the standard deviation. From the same longitudinal study, Brill et al. (2000) investigated body strength associations with long-term functional ability.[25] Their composite used a bench press, a leg press, and an SU test. The composite was determined by dividing each set of test results into three tertiles, allocating 0-2 points (bottom tertile scores zero points), and summing the scores. This study used a composite based on quintiles, as it was hypothesized that five groups would give more precision than three in identifying those at risk.

Fitness test protocol

SBJ was executed with the toes behind the line, and participants jumped as far forward as they could, taking off and landing with both feet. The distance from the start line to the rear-most heel was the score to the nearest centimeter. The better of two jumps was computed. SUs were done with knees bent at right angles and hands cupped behind the ears. One SU was counted each time a participant touched their knees with their elbows and returned to the supine position. This was repeated as many times as possible within 60 seconds. For SR, on the command "go" participants sprinted 10m to pick up a beanbag and then sprinted back to the start to deposit it on the ground. They then sprinted back to pick up a second bag but on return they crossed the finish line with it in hand. The better of two attempts was computed. Data were entered into SPSS and as they were in categories, Chi-Square was used for statistical analysis.

Results

Outliers

PA distribution was highly positively skewed, so outliers were removed from the right tail only. Those removed were overweight participants with PA scores totaling the mean plus two deviations, and obese participants with scores totaling the mean plus 1.5 standard deviations [the assumption was that neither the overweight nor the obese were likely to exhibit these high levels of personal PA]. The sample size was consequently reduced by fourteen from N=638 to N=624.

Anthropometric measurements

The mean age in this study is 19.9 years. Mean height is 173.2 cm which compares with 172.4 cm from similarly aged Thai urban males in the 2009 National Cohort Study.[26] The mean weight is 69.7 kg which compares with 67.1 kg from a mixed urban and rural population (aged around 30) from the same 2009 national survey.[27] Thus, this cohort is a little taller and heavier than the Thai norm. BMI was calculated by dividing weight (kg) by the square of the height (metres). WC was a direct measurement. See Table 1 for details.

Table 1 Participants' BMI, WC, and PA profiles (n=624)

	Mean	S.D.	Normal	Class I	Class II
Age	19.9	1.47			
Height [cm.]	173.2	5.66			
Weight [kg]	69.7	14.00			
*BMI [kg/m^2]	23.2	4.34	58.0% (*n*=357)	16.7% (*n*=103)	25.2% (*n*=155)
WC [cm.]	85.7	10.3	49.4% (*n*=308)	21.3% (*n*=133)	29.3% (*n*=183)
PA[met/week]	2715.5	2630.2	57.2% (*n*=357)	20.7% (*n*=129)	22.1% (*n*=138)

BMI: Normal is <23kg/m^2; Class I (overweight) is 23-24.99 kg/m^2; Class II (obese) is ≥25kg/m^2. WC: Normal is < 85 cm; Class I is 85-89.99 cm; Class II is ≥ 90 cm. PA: Normal is ≥ 1500 met/week (equivalent to 150 min/week of vigorous PA); Class I is 600-1499 met/week (equivalent to 150 min/week of moderate PA); Class II is <600 met/week; *9 missing [N=615].

S.D.=Standard Deviation.

cm.=centimetre

kg=kilogramme

kg/m^2=kilgrammes per square metre

met/week=metabolic units per week

Table 1 also indicates the cut-off points for increased risk. For Thais, a BMI range of 23-24.99 kg/m2 is recommended.[28] For WC, one source advises 84 cm for middle-aged Thai males, another recommends ≥90 cm.[29,30] In the absence of guidelines from WHO for WC, this study incorporates these two cut-offs.

PA data

PA was measured using "metabolic equivalents for the task" (MET). This unit of energy is used to combine different intensity levels in the following manner: Vigorous PA=8 MET/min; Moderate PA=4 MET/min; Walking=3.3 MET/min.[31] It was assumed that the duration reported for a typical day was the average, so this was multiplied by the number of days reported to determine the weekly total (see Table 1). For statistical analysis, PA was split into 3 categories (see under Table 1 for details) and using Chi-Square is significantly associated with BMI and WC. Effect sizes are small (see Table 3 for details).

PF data

Table 2 shows the raw data for the three PF tests and PF Index. Table 3 shows the results of the statistical analyses where these four variables were each split into five quintiles before being computed with BMI and WC (three categories each–see Table 1). Using Chi-square, all results are significant, though PF Index has the highest effect sizes for both BMI and WC.

Table 2 PF test scores and the PF Index [N=624]

Fitness item	Mean	S.D.
Sit-ups [rpm]	25.73	9.20
Shuttle run [sec]	12.87	1.44
Standing Broad Jump [cm.]	190.40	32.25
*PF Index	5.96	3.17

*The PF Index is the sum of the three fitness test scores after each is converted into quintiles: bottom quintile=0 points; top quintile=4 points; max=12 points.

S.D.=Standard deviation

rpm=repetitions per minute

sec=seconds

cm.=centimeter

Table 3 BMI and WC computed with PA and PF variables [N=624]

Fitness item	BMI				WC			
	χ^2	*df*	*p*	V	χ^2	*df*	*p*	V
PA [met/week]	13.117	4	.011.103		15.862	4	.003	.113
Sit-ups [rpm]	32.769	8	.001	.164	31.297	8	.001.	.159.
Shuttle run [sec]	36.537	8	.001.	.173	43.073	8	.001	.186.
Standing Broad Jump [cm.]	35.485	8	.001	.170	30.394	8	.001	.156.
PF Index	50.227	8	.001	.203	56.507	8	.001	.213.

χ^2=Chi-square

df=the number of degrees of freedom

p=significance

V=effect size

met/week=total number of metabolic units per week

rpm=repetitions per minute

sec=second

cm.=centimetre

The bottom quintile

As the population of interest are those most at risk, the focus switched to the bottom quintile, as this is where obesity rates are likely to be preponderant. What percentage of those who rate obese are in the bottom 20% for PA and PF variables? The results for BMI and WC can be seen in Figures 1 and 2 respectively.

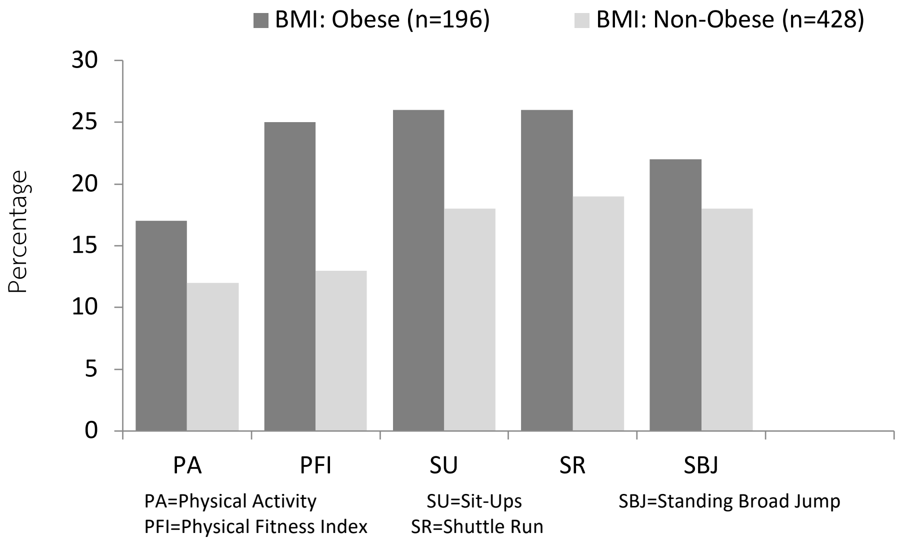

Figure 1 The percentage of the obese and non-obese, as measured by BMI, in the bottom quintile of the five physical activity/fitness variables

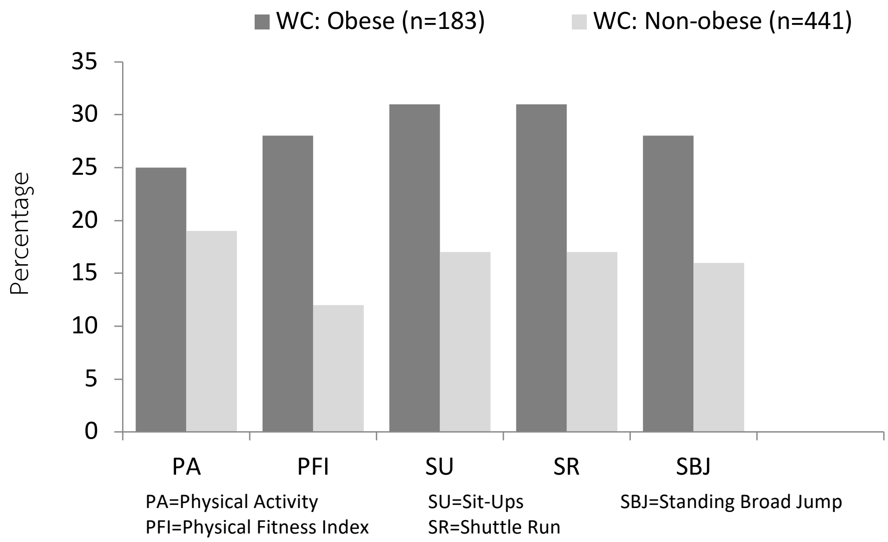

Figure 2 The percetage of obese and non-obese, as measured by WC, in the bottom quintile of the five physical activity/fitness variables

Figures 1 and **2** show that obese participants are proportionally more represented in the bottom quintiles. Additionally, WC has visually wider gaps between the obese and non-obese than BMI, and the fitness variables have wider gaps between the obese and non-obese than PA. PF Index has a slightly wider gap than the other fitness variables.

Discussion

The study asked whether PF or PA is a better proxy for indicating long-term health problems in this cohort by investigating their associations with obesity. Findings indicate that

PF is a better proxy. The other research questions asked whether PA, BMI, WC, and PF are individual causes for concern. Findings indicate that they are.

For RQ1, PF is significantly associated with obesity at p-values≥.001, whereas PA is significant at a slightly higher p-value. PF also has stronger effect sizes by a factor of 2.5 in the case of PF Index. In particular, those rated obese on BMI are nearly twice as likely as the non-obese to score in the bottom quintile on PF index than on PA. This is more pronounced for WC where the differential is four-fold. In short, the objective PF test items are a more reliable “at risk” indicator than the results from the subjective self-report questionnaire for PA. Why might this be so?

First, non-obese participants may have underestimated their PA levels. For example, in a Thai study, nearly two thirds of respondents underestimated PA when compared to their actual pedometer readings.[32] Second, obese participants may have over-reported PA. This was the finding of Cleland et al. (2011) who reported that obese participants scored lower on pedometer-measured PA than on the IPAQ (long form).[33] Alternatively, the IPAQ may not capture the total PA which individuals do but which contributes to their total weekly energy expenditure. In their study of 2,523 students aged 14-18 years, Langlois et al. (2017) found that self-reported PA scores (IPAQ short form) were insufficient to assess the totality of PA.[34]

For RQ2, 22.1% of this cohort failed to reach the WHO recommended minimum of 150 min/week of moderate PA or its equivalent. Elsewhere, and also using the short form of the IPAQ, Bauman et al. (2009) found that 7-41% of individuals [aged 18–65, N=52,746] in 20 countries surveyed (including Taiwan, China, and India) also failed to meet the recommended PA minimum.[17] At “high” PA levels (>3000MET/week), they reported figures of 21-63%. This contrasts with 32% in this study. Overall, for PA this cohort seems at risk and below Asian averages.

For RQ3, when using WHO Asian criteria for BMI, 25.2% of this cohort are obese (≥ 25 Kg/m^2). This is 10-30% higher than similarly-aged student bodies at other Thai universities.[35]

For RQ4, using the WC cut-off point of 90 cm for Thai males, 29.3% of this cohort are obese.[7] This is almost twice the rate of 15.7% reported in the 2004 Thai National Health Survey.[6] In another Thai study (n=616) of males (mean age=35), the WC mean was 83 cm compared to 86 cm in this study.[36] Overall, this cohort fares poorly in comparison to its Thai peers.

For RQ5, obese students are less fit than non-obese students and this chimes with evidence from elsewhere. In a study of 3,214 Flemish youth (aged 12-18), obese students had worse performances on all three PF test items.[14] More specifically, for SU, this study's average (35.9 rpm) is about 7% lower than for a similarly aged male cohort (38.6 rpm) at another Bangkok university.[35] In the Canada Fitness Survey, sit-ups were the strongest predictor of mortality.[37] In their review, Lee and Paffenbarger (1996) concluded that the inverse relationship between PA and all-cause mortality is likely to be causal, and that this probably extends to PF.[38] If so, participants in this study who do not reach the WHO recommended minimum of 150 min/week of vigorous PA, or are unfit, may be set on a trajectory of earlier mortality and/or decreased quality of life in their later years. What can be done?

First, it may be important to recognize that all forms of energy expenditure (e.g. washing up, gardening; climbing stairs) are beneficial. This means that some PA is better than none. In the Australian Health in Men Study, Brown et al. (2012) found that even low levels of PA (300 MET/week) confer a degree of health protection.[39]

Second, diet must also be considered. The rises in T2DM and other non-communicable diseases in Thailand are due in part to a lack of PA and excess sugar in the diet.[40] Thus, PA is only part of the solution. A healthy diet is another.

Finally, how we construct our environment can help, from the design of urban transport schemes, to the layout of urban parks. There are also cultural attitudes that suppress PA uptake, as well as those of class, age, and gender. The interaction between all these may be best understood through an ecological approach with the individual nested within a set of concentric spheres: family; school; wider society. For success, solutions may need to address all of these.

References

1. Lee I-M, Shiroma EJ, Lobelo F, Puska P, Blair SN, Karzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. Lancet 2012;380(9838):219-229.

2. World Health Organization [WHO]. Global Recommendations on Physical Activity for Health. Geneva: WHO, 2010. Available from:https://www.who.int/dietphysicalactivity/factsheet_adults/en/

3. Ng SW, Popkin BM. Time use and physical activity: A shift away from movement across the globe. Obes Rev 2012;13(8):659-680.

4. Hasse A, Steptoe A, Sallis JF, Wardle J. Leisure-time physical activity in university students development. Prev Med 2004;39(1):182-190.

5. Sisson SB, Katzmarzyk PT. International prevalence of physical activity in youth and adults. Obes Rev 2008;9:606-614.

6.Aekplakorn W, Mo-Suwan L. Prevalence of obesity in Thailand. Obes Rev 2009;10:589-592.

7. Aekplakorn W, Hogan MC, Chongsuvivatwong V, Tatsanavivat P, Chariyalertsak S, Boonthum A, et al. Trends in Obesity and Associations with Education and Urban or Rural Residence in Thailand. Obesity 2007;15(12):3113-3121.

8. Abarca-Gomez L, Abdeen ZA, Hamid ZA, Abu-Rmeileh NM, Acosta-Cazares B, Acuin C, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. Lancet 2017;390(10113):2627-2642.

9. Pinhas-Hamiel O, Zeitler P. The global spread of type 2 diabetes mellitus in children and adolescents. J Pediatr 2005;146(5):693-700.

10. Hui WS, Liu Z, Ho SC. Metabolic syndrome and all-cause mortality: a meta-analysis of prospective cohort studies. Eur J Epidemiol 2010;25(6):375-384.

11. Friend A, Craig L, Turner S. The Prevalence of Metabolic Syndrome in Children: A Systematic Review of the Literature. Metab Syndr Relat Disord 2013;11(2):71-80.

12. Aekplakorn W, Kessomboon P, Sangthong R, Chariyalertsak S, Putwatana P, Inthawong R, et al. Urban and rural variation in clustering of metabolic syndrome components in the Thai population: results from the fourth National Health Examination Survey 2009. BMC Public Health 2011;11(854).

13. Brunet M, Chaput J-P, Tremblay A. The association between low physical fitness and high body mass index or waist circumference is increasing with age in children: The 'Québec en Forme' Project. Int J Obes 2007;31:637-643.
14. Deforche B, Lefevre J, de Bourdeaudhuij I, Hills AP, Duquet W, Bouckaert J. Physical Fitness and Physical Activity in Obese and Nonobese Flemish Youth. Obes Res 2003;11:434-441.
15. Bartlett JE, Kotrlik JW, Higgins CC. Organizational Research: Determining Appropriate Sample Size in Survey Research. ITLPJ 2001;19(1):43-50.
16. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International Physical Activity Questionnaire:12-Country Reliability and Validity. Med Sci Sports Exerc 2003;35(8):1381-1395.
17. Bauman A, Bull F, Chey T, Craig CL, Ainsworth BE, Sallis JF, et al. The International Prevalence Study on Physical Activity: Results from 20 countries. Int J Behav Nutr Phys Act 2009;6(21).
18. International Physical Activity Questionnaire [IPAQ] (2002). Downloadable questionnaires. 2002. Available from:https://sites.google.com/site/theipaq/questionnaire_links
19. Rhea MR, Alvar BA, Gray R. Physical fitness and job performance of firefighters. J Strength Cond Res 2004;18(2):348-352.
20. Ortega FB, Artero EG, Ruiz JR, España-Romero V, Jiménez-Pavón D, Vicente-Rodriguez G, et al. Physical fitness levels among European adolescents: The HELENA study. Brit J Sport Med 2011;45(1):20-29.
21. Chen LJ, Fox KR, Haase A, Wang JN. Obesity, fitness and health in Taiwanese children and adolescents. Eur J Clin Nutr 2006;60:1367-1375.
22. Ruiz JR, Castro-Pinero J, Espana-Romero V, Artero EG, Ortega FB, Cuenca MM, et al. Field-based fitness assessment in young people: The ALPHA health-related fitness test battery for children and adolescents. Brit J Sports Med 2010;45(6).
23. Ortega FB, Artero EG, Ruiz JR, Vicente-Rodriguez G, Bergman P, Hagströmer M, et al. Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. Int J Obes 2008;32:S49-S57.

24. Ruiz JR, Sui X, Lobelo F, Morrow JR, Jackson AW, Sjöstrom M, et al. Association between muscular strength and mortality in men: Prospective cohort study. BMJ 2008;337:a439.

25. Brill PA, Macera CA, Davis DR, Blair SN, Gordon N. Muscular strength and physical function. Med Sci Sports Exerc 2000;32(2):412-416.

26. Jordan S, Lim L, Seubsman SA, Bain C, Sleigh A. Secular changes and predictors of adult height for 86105 male and female members of the Thai Cohort Study born between 1940 and 1990. J Epidemiol Community Health 2010;66(1):75-80.

27. Lim L, Banwell C, Bain C, Banks E, Seubsman S-A, Kelly M, et al. Sugar Sweetened Beverages and Weight Gain over 4 Years in a Thai National Cohort: A Prospective Analysis. PLoS One 2014;9(5):e95309.

28. Worachartcheewan A, Dansethakul P, Nantasenamat C, Pidetcha P, Prachayasittikul V. Determining the optimal cutoff points for waist circumference and body mass index for identification of metabolic abnormalities and metabolic syndrome in urban Thai population. Diabetes Res Clin Pract 2012;98(2):e16-e21.

29. Narksawat K, Podang J, Punyarathabundu P, Podhipak A. Waist circumference, body mass index and health risk factors among middle aged Thais. Asia Pac J Public Health 2007;19(3):10–15.

30. Aekplakorn W, Chongsuvivatwong V, Tatsanavivat P, Suriyawongpaisal P. Prevalence of Metabolic Syndrome Defined by the International Diabetes Federation and National Cholesterol Education Program Criteria Among Thai Adults. Asia Pac J Public Health 2011;23(5):792-800.

31. Patterson E. Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ). IPAQ Scoring Protocol. 2005. Available from: https://sites.google.com/site/theipaq/scoring-protocol

32. Sitthipornvorakul E, Janwantanakul P, van der Beek AJ. Correlation between pedometer and the Global Physical Activity Questionnaire on physical activity measurement in office workers. BMC Res Notes 2014;7(1):Article Number 280.

33. Cleland VJ, Schmidt MD, Salmon J, Dwyer T, Venn A. Correlates of pedometer-measured and self-reported physical activity among young Australian adults. J Sci Med Sport 2011;14(6):496-503.
34. Langlois J, Omorou AY, Vuillemin A, Briancon S, Lecomte E. Association of socioeconomic, school-related and family factors and physical activity and sedentary behaviour among adolescents: Multilevel analysis of the PRALIMAP trial inclusion data. BMC Public Health 2017;17(1):1-14.
35. Sookhanaphibarn T, Choensawat W. Standardized Test System of Health-related Physical Fitness for Thai College Students. Procedia Manuf 2015;3:1527-1534.
36. Lim LLY, Seubsman S, Sleigh A, Bain C. Validity of self-reported abdominal obesity in Thai adults: A comparison of waist circumference, waist-to-hip ratio and waist-to-stature ratio. Nutr Metab Cardiovasc Dis 2012;22(1):42-49.
37. Katzmarzyk PT, Craig CL. Musculoskeletal fitness and risk of mortality. Med Sci Sport Exer 2002;34(5):740-744.
38. Lee I-M, Paffenbarger RS. Do Physical Activity and Physical Fitness Avert Premature Mortality? Exerc Sport Sci Rev 1996;24(1):135-172.
39. Brown WJ, McLaughlin D, Leung J, McCaul KA, Flicker L, Almeida OP, et al. Physical activity and all-cause mortality in older women and men. Br J Sports Med 2012;46(9):664-68.
40. Chavasit V, Kriengsinyos W, Photi J, Tontisirin K. Trends of increases in potential risk factors and prevalence rates of diabetes mellitus in Thailand. Eur J Clin Nutr 2017;71:839-843.