Evaluating of the Axivity accelerometers algorithm in measurement of physical activity intensity in boys and girls

Maedeh Mansoubi (mmansoubi@brookes.ac.uk)
Oxford Brookes University https://orcid.org/0000-0002-8829-2217
Patrick Esser
Oxford Brookes University
Andy Meaney
Oxford Brookes University
Renske Metz
Zuyd University
Kyle Beunder
Zuyd University
Helen Dawes
Oxford Brookes University

Research article

Keywords: Shuttle run, Physical activity, SVM, Axivity, AX3, Cardiorespiratory Fitness, Adolescents

Posted Date: December 4th, 2019

DOI: https://doi.org/10.21203/rs.2.18186/v1

Abstract

Background: Accelerometers are new but popular tools in measurement of physical activity level but most of them use the algorithms which are more suitable for adults rather than adolescents. Also accelerometers accuracy in assessing physical activity intensity in boys and girls is widely unknown. Therefore, purpose the current study was to evaluate the validity of the Axivity accelerometers in relation to establish algorithm in the measurement of physical activity intensity in boys and girls.

Methods: A total of 143 participants recruited from a local school in Oxfordshire and 119 of them (84 boys and 35 girls, age (12.71 ± 0.46)) completed the shuttle run test while wearing an AX3 accelerometer. Signal Vector Magnitude (gravity-subtracted) (SVMgs) and Metabolic equivalent (MET) values were calculated for both of boys and girls.

Results: The study result showed that girls had significantly higher SVMgs value ($P< 0.05$) while according to the standard equations, girls have lower VO2max and MET in each shuttle run lap.

Conclusion: This study result suggest that different algorithms might be necessary to measure physical activity in different genders.

Background

Growing level of the obesity and reducing cardio-fitness in adolescents' raises a major concern about global health.[1]A systematic review by Strong et al (2005) showed that adolescents need have at least 60 minutes of MVPA per day.[2] Population surveys show that many of the youth are less active than guidelines. Though it's been estimated that about 80% of adolescents have around 30 minutes of physical activity each day.[3] Furthermore according to Hallal et al (2012), 80% of adolescents (13- 15 years old) worldwide have less than 60 minutes of moderate to vigorous physical activity (MVPA) per day which this amount is lower in higher income countries.[4]

There are several studies which show the effect of regular physical activity on reducing chronic disease in adolescents and its later effect during middle age.[5–7]Also it's been shown that better Cardiorespiratory Fitness (CRF) in adolescents is associated with less risk of myocardial infarction in adulthood.[8] CRF is the ability of the body to supply the muscles' oxygen and to employ this oxygen to produce enough energy for conducting physical activity.[9,10] Maximal oxygen consumption (VO2max) is considered by the World Health Organization (WHO) to be the best cardiorespiratory fitness indicator.[11]

There are different ways for physical and cardiorespiratory fitness assessment in adolescents, but 20-meter Shuttle Run Test is the most popular one[12,13] and frequently being used in cardiorespiratory fitness studies.[14] For example a recent research (Fit to study) is using the test for evaluating cardio fitness in 100 secondary schools in UK (https://www.fit-to-study.org/). The shuttle run, is included in a broad number of physical fitness test batteries. One of the most frequently-used versions is the PACER (Progressive Aerobic

Cardiovascular Endurance Run), the standard CRF test for the FITNESSGRAM battery.[15] Based on the evidence, physical activity level could be another indicator of physical fitness Also MVPA can advance the strength, cardiorespiratory fitness, body composition and reduce the cardiovascular risk factors in adolescents.[5–7]

There are several studies which explore different objective and subjective physical activity assessment methods in adolescents and children.[6, 7,16,17,18] Accelerometers are a popular choice of instrument for the objective measurement of physical activity intensity. Accelerometers are portable devices which categorise the physical activity level base on the Signal Vector Magnitude (SVM) in three different Axis (vertical(Y), horizontal right-left (X) and horizontal front-back axis (Z)).[19] However, there is one study which used the accelerometers (Geneactiv) for the objective measurement of physical activity in adolescents during shuttle run test[16] and two recent studies which measured validity of the Axivity device wearing at thigh and back [20, 21] but to date there is no evidence to evaluate accuracy of the wrist worn Axivity algorithms using the (SVM) during a vigorous activity and comparing results between boys and girls.

Given the likelihood that shuttle run test and accelerometers will continue to be used by researchers as a tool to measure physical fitness and physical activity level in adolescents, aim of the current study was to evaluate the extent of the strength of relationship of SVM algorithms in measurement of physical activity intensity alongside of evaluating the SVM and cardio-fitness differences in boys and girls.

Materials And Methods

Design

A Cross sectional study design.

Population

All of the participants were recruited from a local school in Oxfordshire. Ethical approval granted by Oxford Brookes University Ethical Advisory Committee. Permission was gained from each school’s head teachers to recruit participants, and opt-out consent was collected from each participant’s parent or legal guardian.

Measurements

Anthropometric measures were taken which included height (measured using a portable stadiometer, Seca UK), waist circumference (measured mid-way between the lower rib margin and the iliac crest using anthropometry tape), and body weight and composition (measured using a Tanita Body Composition Analyser, model: BC–418 MA, Tanita, UK).

Cardiorespiratory fitness measure

Shuttle run test used for the cardiorespiratory fitness evaluation. Total of 119 participants completed shuttle run test which according to the FITNESSGRAM (PACER), the test consists in running back and forth between two lines 20 meters apart, with running speed determined by audio signals from a pre-recorded music CD.[15] The running speed increases at the end of each one-minute stage. The running speed is 8.0 km.h–1 for the first stage, 9.0 km.h–1 for the second stage, and thereafter increases by 0.5 km.h–1 each minute. The test ends when the subjects twice fail to reach the lines at the time indicated by the audio signals, demonstrating an inability to keep the required pace.[15]

AX3

All the participants wore a wrist-band accelerometer during whole shuttle run test. AX3 accelerometer was attached, using a watch strap positioned on the dorsal aspect of participants' non-dominant hand. The AX3 (axivity, UK) which was used in this study as a measuring device is a continuous logging accelerometer that has been designed to monitor physical activity intensity and duration. It is a triaxial, ±16g acceleration sensor housed in a small (23 x 32.5 x 7.6 mm), light weight (11 g) and encased splash-proof. The sampling frequency of the AX3 ranges from 12.5 Hz to 3200 Hz and the battery can last up to 14 days when recording data at 100 Hz.

Data processing and statistical analyses

There are several methods and equations to estimate VO2max during SR test in adolescents.[22]One of these methods is Multiple Linear Regression (MLR) model which is a stepwise method.[23–26]Another method is Artificial Neural Networks (ANN) models which has been validated by Ruiz et al in (2008 and 2009) for VO2max assessment in adolescents.[27, 28] Also this method is widely being used in different studies.[26, 29–32]

Raw 100 Hz triaxial Ax3 data was analysed in a bespoke LabVIEW programme (National Instruments, Newbury, UK) in accordance with the manufacturers analytics (Open movement V1.0.0.37). Below equation used to calculate the signal vector magnitude (gravity-subtracted) (SVM_{gs}), in 1s epochs.[33] According to Esliger et al (2011) the unit of the following equation result would be gs.[34]

[Due to technical limitations the formula could not be displayed here. Please see the supplementary files section to access the formula.]

In addition, a bespoke programme was used to calculated the estimated VO2max for each participant using three different methodologies considering participants' sex, age, height, weight, body mass index (BMI) and Pacer laps according to Mahar et al 2011[22], Multiple Linear Regression (MLR) [23–26] and using artificial neural networking (ANN) methodologies[27, 28]

To achieve the MET values associated with each level of shuttle run, VO2 values were converted to METs using age specific values.The MET values were calculated using the standardized MET formula for adolescents:

1 MET = 5.92 ml kg $^{-1}$ min^{-1} (8–12 boys/8–11 girls) and 4.85 ml kg $^{-1}$ min^{-1} (13–15 boys/12–14 girls).[35]

The Shapiro-Wilk test confirmed that all data were normally distributed. Also SVMgs average calculated for each shuttle run level and compared between genders using univariate variance test. In the event of a significant ANOVA result, Bonferroni -corrected post hoc comparisons were undertaken to determine where the significant differences occurred. Differences between the BMI groups were tested using independent t-tests. P < 0.05 was considered significant and all tests were 2-sided. All statistical analyses were performed using SPSS version 25 (IBM SPSS Statistics). Data are displayed as mean (± SD) and mean (95 % CI) in the text and tables.

Result

A total of 143 participants recruited from a local school in Oxfordshire and 119 of them (84 boys and 35 girls age (12.71 ± 0.46), Height (164.39 ± 8.51), Weight (51.80 ± 11.85) completed the study in April and May 2016. The characteristics of the participants are displayed in Table 1. Six Girls completed 7 laps and 30 boys finished the level 9 of shuttle run test. Numbers of participants which finished each shuttle run laps are demonstrated in table 2.

SVM Mean ± SD values calculated during all shuttle run laps and results compared between boys and girls (table 2). Average of participants SVMgs in lap 1 was (0.80±0.14), lap 2 (1.21±0.16), lap 3 (1.26±0.17), lap 4 (1.32±0.17), lap 5 (1.35±0.18), lap 6 (1.37±0.18), lap 7 (1.40±0.21), lap 8 (1.39±0.18), lap 9 (1.44±0.20). Girls had significantly (p<0.05) higher SVMgs values rather than boys in each shuttle run lap. (Table 3 and figure 1).

MET Mean ±SD values calculated during all shuttle run laps for boys and girls using three different MET equations for adolescents based on the Mahar 2011, MLR and ANN VO_{2max} equations (Table 2). According to Mahar equation, average of participants MET in lap 1 was (5.93±0.49), lap 2 (6.49±0.49), lap 3 (7.04±0.48), lap 4 (7.60±0.43), lap 5 (8.11±0.40), lap 6 (8.56±0.37), lap 7 (8.95±0.33), lap 8 (9.28±0.20), lap 9 (9.41±0.17). Girls consistently had lower VO_{2max} and MET values rather than boys (table 2).

Discussion

We observed that the SVM_{gs} was significantly higher in girls than boys with girls having a higher level of physical activity intensity and higher MET during the shuttle run test with standard formulas (Mahar et al, 2011; MLR and ANN). MET is an indicator of Physical activity intensity[36] and sedentary behaviour is ranged (1.0–1.5 METs)[35,36] and light-intensity is (1.6–2.9 METs)[37, 39], moderate-intensity (3–5.9 METs), and vigorous-intensity (≥6 METs) activities.[40] Therefore we found that shuttle run test started in the vigorous physical activity level in both genders. Also based on the standard formula results, girls to have a lower MET level during all the shuttle run laps. There are limited studies which have compared the MET in boys and girls but this result is broadly consistent with other studies which comparing the energy expenditure and METs in male and females during different activities. For example a study result by Zunzer et al (2013) showed that male golf players had significantly higher energy expenditure and MET rather than female participants.[41] Based on the evidence and current study MET result, we expected girls to have a lower physical activity intensity during per shuttle run lap but accelerometer data showed that female participants had a significantly higher SVM_{gs} rather than boys per shuttle run level. It might be because of the running economy or lower coordination level in girls. A study result by Telford et al, (2016) showed that girls had 44% lower eye-hand coordination during physical activity[42] and it could be a reason of the accelerometers SVM_{gs} over estimating. Present study is the first research which compared the AX3, SVMgs results in adolescent boys and girls. Therefore further researches are required to confirm this result but base on the current study result, the AX3 accelerometer algorithm might need re-assessment to have the more accurate physical activity measurement for this age group in boys and girls.

Current study provided an evidence of cardio-fitness in boys and girls during shuttle run test. In the present study girls completed 7 levels and boys finished 9 levels of shuttle run laps. It could indicate that girls have a lower level of cardio-fitness rather than boys. This result is broadly consistent with other studies. For example a systematic review result by Tomkinson et al (2016) in 1142026 children age (9–17) during shuttle run test showed that boys had a better performance than girls in all the age groups.[43] Furthermore a study by Lintu et al (2015) in 9–11 years old children demonstrated that boys had a better cardio respiratory fitness rather than girls.[44] Also another study result in 7244 students (9–17.9) by Ramírez-Vélez et al, (2017) showed that boys had a higher shuttle and VO2peak in all of the age groups rather than girls.[45] This gender differences in cardio-fitness level could be because of the lower level of physical activity in girls rather than boys. A study result by Telford et al (2016) in 276 boys and 279 girls from 29 schools showed that girls 19% less active than boys and their cardio respiratory fitness was 18% less than boys.[42] This lower level of physical activity could have a negative impact on girls' health in adulthood. Therefore designing different interventions to increase physical activity level in girls could improve the cardio-fitness in them.

The limitations of this study include having relatively small sample size and not measuring the actual VO2max and resting metabolic rate in participants. Study strengths however include the novel assessment and comparison of Axivity SVM data during an observed free living style activity in boy and girl adolescents.

Conclusion

Current study presents important and novel finding that when using the Ax3 accelerometer raw data and comparing the result between male and female participants. Current study result showed that the SVM result was significantly different between genders and gone higher intensity levels for same shuttle lap in girls. This suggests that a different accelerometer algorithm might be required for accurate measurement of physical activity intensity in boys and girls. Further research is now required with more participants and different age groups of adolescents to confirm this result alongside actual measures of energy expenditure.

Declarations

Ethics approval and consent to participate

Ethical approval granted by Oxford Brookes University Ethical Advisory Committee. Permission was gained from each school's head teachers to recruit participants, and opt-out consent was collected from each participant's parent or legal guardian.

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are available from Oxford Brookes University but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Oxford Brookes University.

Competing interests

"The authors declare that they have no competing interests"

Funding

This work is supported by Elizabeth Casson Trust (ECT), EEF, NIHR Oxford Biomedical Centre (BRC) and the CLEAR trust.

Role of funding source

Authors declare that funding sources had no involvement in study design, collection, analysis and interpretation of data, in the writing of the report and the decision to submit the article for publication.

Acknowledgements

We would like to acknowledge members of the Movement Science Group (MOReS) at Oxford Brookes University for their commitment and support.

Authors’ contribution

MM, PE and HD conceived the study and contributed towards its design. AM, RM and KB were responsible for the acquisition of data. MM, PE and HD performed the statistical analysis and interpretation. MM, HD and PE were involved in drafting the manuscript. AM, RM and KB revised the manuscript for important intellectual content. All authors gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All authors read and approved the final manuscript.

References

1. Lobstein T, Baur L, Uauy R; IASO International Obesity TaskForce. Obesity in children and young people: a crisis in public health. Obes Rev. 2004;5(Suppl 1):4–104. Pub-Med http://dx.doi.org/10.1111/j.1467–789X.2004.00133.x
2. Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, Hergenroeder AC, Must A, Nixon PA, Pivarnik JM, Rowland T, Trost S, Trudeau F. Evidence based physical activity for school-age youth. J Pediatr. 2005; Jun; 146(6):732–7.
3. Pate R, Long B, Heath G. Descriptive epidemiology of physical activity in adolescents. Pediatr. Exerc. Sci. 1994; 6:434– 447.
4. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Lancet Physical Activity Series Working Group. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet. 2012; Jul 21; 380(9838):247–57. doi: 10.1016/S0140–6736(12)60646–1.
5. Landry BW, Driscoll SW. Physical activity in children and adolescents. PM R. 2012; Nov; 4(11):826–32. doi: 10.1016/j.pmrj.2012.09.585.
6. Dencker M, Andersen LB. Accelerometer-measured daily physical activity related to aerobic fitness in children and adolescents. J Sports Sci. 2011; Jun;29(9):887–95. doi:10.1080/02640414.2011.578148.
7. Dencker M, Andersen LB. Health-related aspects of objectively measured daily physical activity in children. Clin Physiol Funct Imaging. 2008 May;28(3):133–44. doi: 10.1111/j.1475–097X.2008.00788.x. Epub 2008 Feb 2.
8. Högström G, Nordström A, Nordström P. High aerobic fit-ness in late adolescence is associated with a reduced risk of myocardial infarction later in life: a nationwide cohort study in men. Eur Heart J. 2014; 35(44):3133–40. PubMed http://dx.doi.org/10.1093/eurheartj/eht527
9. Armstrong N, Tomkinson GR, Ekelund U. Aerobic fitness and its relationship to sport, exercise training and habitual physical activity during youth. Br J Sports Med. 2011; Sep; 45(11):849–58. doi:

10.1136/bjsports–2011–090200.

10. Institute of Medicine. Health-related fitness measures for youth: cardiorespiratory endurance. In: Institute of Medicine, ed. Fitness measures and health outcomes in youth. Washington DC: The National Academy Press. 2012; 111–51.
11. Shephard RJ, Allen C, Benade AJ, Davies CT, Di Prampero PE, Hedman R, et al. The maximum oxygen in-take. An international reference standard of cardiorespira-tory fitness. Bull World Health Organ. 1968; 38(5):757–64. PubMed
12. Léger LA, Mercier D, Gadoury C, and Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. J Sports Sci.1988; 6:93–101.
13. Mayorga-Vega D, Aguilar-Soto P, Viciana J. Criterion-Related Validity of the 20-M Shuttle Run Test for Estimating Cardiorespiratory Fitness: A Meta-Analysis. J Sports Sci Med. 2015; Aug 11; 14(3):536–47. eCollection 2015 Sep.
14. Quinart S, Mougin F, Simon-Rigaud ML, Nicolet-Guénat M, Nègre V, Regnard J. Evaluation of cardiorespiratory fitness using three field tests in obese adolescents: validity, sensitivity and prediction of peak VO2. J Sci Med Sport. 2014; Sep; 17(5):521–5. doi: 10.1016/j.jsams.2013.07.010. Epub 2013 Aug 12.
15. The Cooper Institute for Aerobics Research. Fitnessgram & Activitygram Test Administration Manual. Champaign, Illinois, USA: Human Kinetics, 2010.
16. Silva G, Andersen LB, Aires L, Mota J, Oliveira J, Ribeiro JC. Associations between sports participation, levels of moderate to vigorous physical activity and cardiorespiratory fitness in children and adolescents. J Sports Sci. 2013; 31(12):1359–67. doi:10.1080/02640414.2013.781666. Epub 2013 Apr 30.
17. Phillips LR, Parfitt G, Rowlands AV. Calibration of the GENEA accelerometer for assessment of physical activity intensity in children. J Sci Med Sport. 2014; 16: 124–128
18. Roscoe CMP, James RS, Duncan MJ, Calibration of GENEActiv accelerometer wrist cut-points for the assessment of physical activity intensity of preschool aged children. Eur J Pediatr. 2017 Aug; 176(8):1093–1098. doi: 10.1007/s00431–017–2948–2. Epub 2017 Jul 3.
19. Chen KY, Bassett DR, The technology of accelerometry-based activity monitors: current and future. Med Sci Sports Exerc. 2005 Nov; 37(11 Suppl):S490–500.
20. Stewart T, Narayanan A, Hedayatrad L, Neville J, Mackay L, Duncan S. A Dual-Accelerometer System for Classifying Physical Activity in Children and Adults. Med Sci Sports Exerc. 2018 Dec;50(12):2595–2602. doi: 10.1249/MSS.0000000000001717.
21. Schneller MB, Bentsen P, Nielsen G, Brønd JC, Ried-Larsen M, Mygind E, Schipperijn J. Measuring Children’s Physical Activity: Compliance Using Skin-Taped Accelerometers. Med Sci Sports Exerc. 2017 Jun;49(6):1261–1269. doi: 10.1249/MSS.0000000000001222.
22. Mahar MT, Guerieri AM, Hanna MS, Kemble CD. Estimation of aerobic fitness from 20-m multistage shuttle run test performance. Am J Prev Med. 2011;41(4 Suppl 2):S117–23.

23. Preacher KJ, Curran PJ, & Bauer DJ. Computational Tools for Probing Interactions in Multiple Linear Regression, Multilevel Modeling, and Latent Curve Analysis. Journal of Educational and Behavioral Statistics. 2006; 31(4), 437–448. https://doi.org/10.3102/10769986031004437
24. Barnett A, Chan LYS, and Bruce IC. A preliminary study of the 20-m multistage shuttle run as a predictor of peak VO2 in Hong Kong Chinese students. Pediatr Exerc Sci. 1993; 5: 42–50.
25. Matsuzaka A, Takahashi Y, Yamazoe M, Kumakura N, Ikeda A, Wilk B, and Bar-Or O. Validity of the multistage 20-m shuttle-run test for Japanese children, adolescents, and adults. Pediatr Exerc Sci. 2004; 16:113–125.
26. Silva G, Oliveira N, Aires L, Mota J, Oliveira J, Ribeiro J. Calculation and validation of models for estimating VO2max from the 20-m shuttle run test in children and adolescents. Archives of Exercise in Health and Disease, North America, 3, jul. 2011. Available at: <http://ciafel.fade.up.pt/aehd/index.php/aehd/article/view/20>. Date accessed: 17 May. 2018.
27. Ruiz JR, Ramirez-Lechuga J, Ortega F, Castro-Pinero J, Benitez JM, Arauzo-Azofra A, Sanchez C, Sjöström M, Castillo M, Gutierrez A, and Zabala M. Artificial neural network-based equation for estimating VO2max from the 20 m shuttle run test in adolescents. Artif Intell Med. 2008 Nov;44(3):233–45. doi: 10.1016/j.artmed.2008.06.004. Epub 2008 Aug 8.
28. Ruiz JR, Silva G, Oliveira N, Ribeiro J, Oliveira J, and Mota J. Criterion-related validity of the 20-m shuttle run test in youths aged 13–19 years. J Sports Sci. 2009; 27:899–906.
29. Baxt WG. Application of artificial neural networks to clinical medicine. Lancet. 1995; 346:1135–1138.
30. Itchhaporia D, Snow PB, Almassy RJ, and Oetgen WJ. Artificial neural networks: Current status in cardiovascular medicine. J Am Coll Cardiol. 1996; 28: 515–521.
31. Linder R, Mohamed EI, De Lorenzo A, and Pöppl SJ. The capabilities of artificial neural networks in body composition research. Acta Diabetologica. 2003; 40: S9-S14.
32. Ravé JMG and Prieto JAA. Potential challenges in physical education through the knowledge of Artificial Neural Networks. Journal of Human Movement Studies. 2003; 45:81–96
33. Karantonis DM, Narayanan MR, Mathie M et al. Implementation of a real-time human movement classifier using a triaxial accelerometer for ambulatory monitoring. IEEE Trans Inf Technol Biomed. 2006; 10(1): 156–167.
34. Esliger DW, Rowlands AV, Hurst TL et al. Validation of the GENEA accelerometer. Med Sci Sports Exerc. 2011; 43: 1 085- 1 093.
35. Harrell J, McMurray R, Bagget C et al. Energy costs of physical activity in children and adolescents. Med Sci Sports Exerc. 2005; 37:329–336.
36. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011 Aug; 43(8):1575–81. doi: 10.1249/MSS.0b013e31821ece12.
37. Catley MJ, Tomkinson GR. Normative health-related fitness values for children: analysis of 85347 test results on 9–17-year-old Australians since 1985. Br J Sports Med. 2013; 47:98–108.

38. Vandongen R, Jenner DA, Thompson C, et al. A controlled evaluation of a fitness and nutrition intervention program on cardiovascular health in 10- to 12-year-old children. Prev Med. 1995; 24:9–22.
39. Cohen J. Statistical power analysis for the behavioral sciences. 2nd edn. New Jersey: Lawrence Erlbaum, 1988.
40. Eisenmann JC, Katzmarzyk PT, Perusse L. Aerobic fitness, body mass index, and CVD risk factors among adolescents: the Québec family study. Int J Obes. 2005; 29:1077–83.
41. Zunzer SC, von Duvillard SP, Tschakert G, Mangus B, Hofmann P. Energy expenditure and sex differences of golf playing. J Sports Sci. 2013; 31(10):1045–53. doi: 10.1080/02640414.2013.764465. Epub 2013 Jan 30.
42. Telford RM, Telford RD, Olive LS, Cochrane T1, Davey R. Why Are Girls Less Physically Active than Boys? Findings from the LOOK Longitudinal Study. PLoS One. 2016 Mar 9;11(3):e0150041. doi: 10.1371/journal.pone.0150041. eCollection 2016.
43. Tomkinson GR, Lang JJ, Tremblay MS, Dale M, LeBlanc AG, Belanger K, Ortega FB, Léger L. International normative 20 m shuttle run values from 1 142 026 children and youth representing 50 countries. Br J Sports Med. 2017 Nov; 51(21):1545–1554. doi: 10.1136/bjsports–2016–095987. Epub 2016 May 20.
44. Lintu N, Viitasalo A, Tompuri T, Veijalainen A, Hakulinen M, Laitinen T, Savonen K, Lakka TA. Cardiorespiratory fitness, respiratory function and hemodynamic responses to maximal cycle ergometer exercise test in girls and boys aged 9–11 years: the PANIC Study. Eur J Appl Physiol. 2015 Feb; 115(2):235–43. doi: 10.1007/s00421–014–3013–8. Epub 2014 Oct 2.
45. Ramírez-Vélez R, Palacios-López A, Humberto Prieto-Benavides D, Enrique Correa-Bautista J, Mikel Izquierdo M, Alonso-Martínez A, Lobelo F. Normative reference values for the 20 m shuttle-run test in a population-based sample of school-aged youth in Bogota, Colombia: the FUPRECOL study. Am J Hum Biol. 2017 Jan-Feb; 29(1): e22902. Published online 2016 Aug 8. doi: 10.1002/ajhb.22902

Tables

Gender	Number	Age ± SD	Height ± SD (cm)	Weight ± SD (kg)	BMI	Max shuttle run laps
Female	35	12.63 ± 0.49	163.39 ± 7.58	51.93 ± 11.52	19.33 ± 3.41	7
Male	84	12.74 ± 0.44	164.81 ± 8.88	51.75 ± 12.06	18.88 ± 3.16	9
Total	119	12.71 ± 0.46	164.39 ± 8.51	51.80 ± 11.85	19.01 ± 3.23	9

Table 1: descriptive

Shuttle level	Gender	Number	Percent Completed Per lap	SVM±SD	MET Mahar 2011 ±SD	MET MLR 2012 ±SD	MET ANN 2012 ±SD
Lap 1	Male	84	100%	0.77±0.13	6.16±0.32	7.04±0.30	6.90±0.58
	Female	35	100%	0.86±0.15	5.37±0.35	6.23±0.32	5.28±0.49
	Total	119	100%	0.80±0.14	5.93±0.49	6.80±0.48	6.42±0.93
Lap 2	Male	84	100%	1.17±0.15	6.73±0.32	7.51±0.30	7.30±0.60
	Female	35	100%	1.29±0.17	5.93±0.36	6.69±0.32	6.14±0.53
	Total	119	100%	1.21±0.16	6.49±0.49	7.27±0.48	6.96±0.78
Lap 3	Male	84	100%	1.23±0.16	7.27±0.33	7.98±0.30	7.70±0.59
	Female	34	97.14%	1.33±0.18	6.49±0.33	7.18±0.30	6.96±0.53
	Total	118	99.16%	1.26±0.17	7.04±0.48	7.75±0.0.47	7.49±0.67
Lap 4	Male	82	97.62%	1.28±0.15	7.79±0.33	8.45±0.30	8.12±0.50
	Female	28	80%	1.42±0.20	7.06±0.20	7.70±0.18	7.76±0.42
	Total	110	92.44%	1.32±0.17	7.60±0.43	8.26±0.43	8.03±0.51
Lap 5	Male	80	95.24%	1.32±0.17	8.26±0.30	8.93±0.28	8.48±0.46
	Female	20	57.14%	1.48±0.20	7.55±0.19	8.19±0.18	8.45±0.44
	Total	100	84.03%	1.35±0.18	8.11±0.40	8.78±0.40	8.47±0.45
Lap 6	Male	74	88.10%	1.35±0.17	8.65±30	9.38±0.28	8.78±0.42
	Female	11	31.43%	1.53±0.18	7.95±0.21	8.65±0.21	9.14±0.41
	Total	85	71.43%	1.37±0.18	8.56±0.37	9.28±0.37	8.83±0.43
Lap 7	Male	59	70.24%	1.38±0.19	9.01±0.27	9.88±0.26	9.06±0.40
	Female	6	17.14%	1.62±0.27	8.30±0.14	9.11±0.15	9.64±0.36
	Total	65	54.62%	1.40±0.21	8.95±0.33	9.81±0.34	9.11±0.43
Lap 8	Male	46	54.76%	1.39±0.18	9.28±0.20	10.34±0.22	9.33±0.33
	Female	0	0	-	-	-	-
	Total	46	38.66%	1.39±0.18	9.28±0.20	10.34±0.22	9.33±0.33
Lap 9	Male	30	35.71%	1.44±0.20	9.41±0.17	10.82±0.18	9.64±0.32
	Female	0	0	-	-	-	-
	Total	30	25.21%	1.44±0.20	9.41±0.17	10.82±0.18	9.64±0.32

Table 2: Shuttle level intensity according to SVM and MET among adolescents.

Shuttle run level	B	Std. Error	t	P level	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	0.89	0.19	**4.79**	0.000	0.52	1.24
Lap 1	-0.03	0.19	-0.15	0.883	-0.36	0.34
Lap 2	0.41	0.19	**2.17**	0.030	0.04	0.77
Lap 3	0.44	0.19	**2.36**	0.019	0.07	0.81
Lap 4	0.53	0.19	**2.82**	0.005	0.16	0.89
Lap 5	0.59	0.19	**3.14**	0.002	0.22	0.96
Lap 6	0.65	0.19	**3.38**	0.001	0.27	1.03
Lap 7	0.74	0.17	**4.31**	0.000	0.40	1.08
Lap 8	0.75	0.17	**4.36**	0.000	0.41	1.09
Lap 9	0.81	0.17	**4.66**	0.000	0.47	1.15

*. The mean difference is significant at the 0.05 level

Table 3: SVM differences between genders for each level during shuttle run among adolescents

Figures

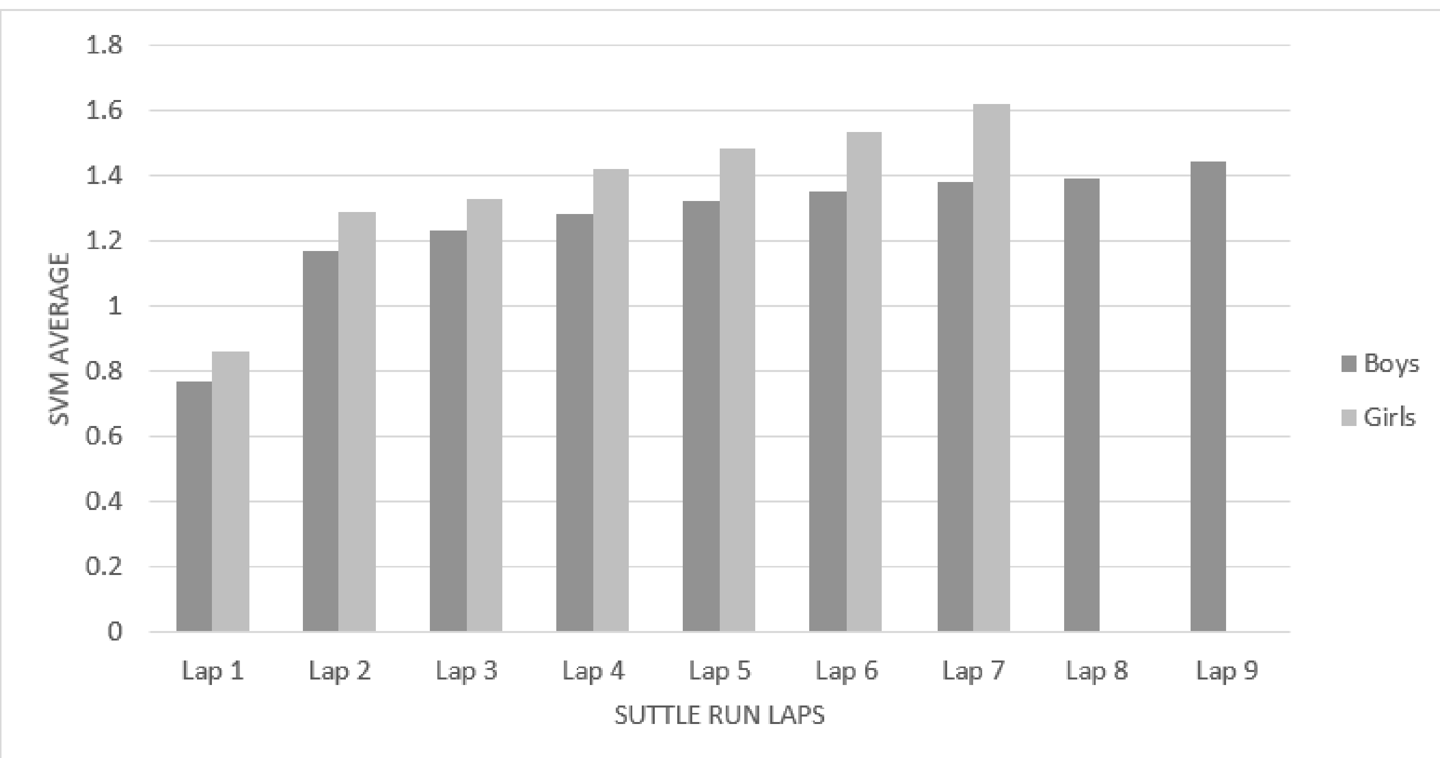

Figure 1

Gender differences in SVM during shuttle run among adolescents

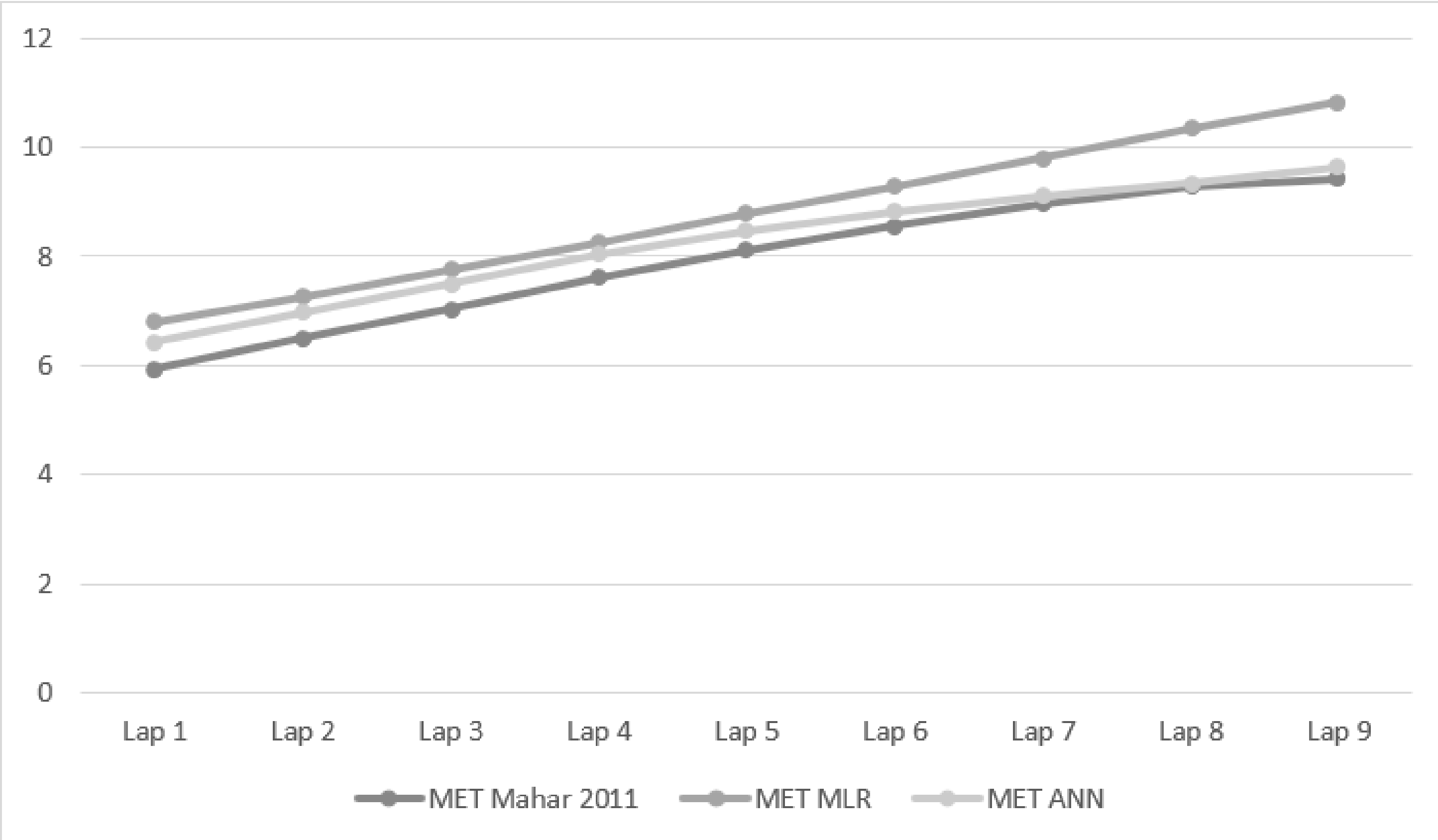

Figure 2

Calculated METs based on the Mahar VO2max, MLR VO2max and ANN VO2max among adolescents.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Methodsformula.docx