Cardio-respiratory fitness markers among Kenyan university students using a 20m shuttle run test (SRT)

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Abstract

Aim: To assess Cardio-respiratory fitness (CF) markers among university students using a 20m shuttle run test (SRT).

Methods: Markers of CF were assessed in 80 males aged 21.4±1.8 years, randomly selected from Moi University, Kenya. Assessed at different stages of SRT protocol included heart rate (HR), systolic and diastolic blood pressure (SBP & DBP). VO_{2max} was also determined. Data were analyzed using Stata v10. Comparisons were based on subjects exercise regimes.

Results: Subjects with either regular or irregular regimes attained lower HR in 4th minute of SRT compared to non-exercise group (174.5±11.6 and 172.2±10.8 vs 182.8±6.8 b/m; $p=0.04$ and $p=0.01$ respectively). Lower HRs were maintained among irregularly exercising after 5th minute (176.5±10.1 vs 186.7±6.3 b/m; $p=0.02$). Regularly exercising subjects obtained lowest DBP at exhaustion compared to irregular and non-exercising (58.58±15.0, 62.43±12.9 and 64.1±8.8 mmhg respectively). VO_{2max} predictors included year of study ($r=-0.40$), age ($r=-0.41$) and weight ($r=-0.23$). The regularly exercising had higher VO_{2max} than irregular ($p<0.01$) and non-exercising ($p<0.001$). No demonstrable difference in VO_{2max} existed between irregular and non-exercise subjects.

Conclusion: Exercise regimes should be emphasized amongst university students, albeit with less regard to regularity, which should be encouraged for those in higher study years and those with higher DBP at exhaustion.

Key words: cardio-respiratory fitness, exercise.

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Introduction

Physical fitness (PF) is crucial to health among all age brackets, with benefits such as maintenance of lipid profile, regulation of blood pressure (BP) and control of cardiovascular ailments.[1-3] Various valid techniques for its assessment exist and include measurement of physiological markers of BP, heart rate (HR) and aerobic capacity - percentage of maximal oxygen uptake (VO_{2max}). These markers are crucial in assessment of cardio-respiratory fitness (CF). Methods for these measurements include the use of laboratory based doubly labelled water calorimetry,[4] a cycle ergometer, treadmill test and the now increasingly popular field tests such as the 20 m shuttle run test (SRT).

The doubly labelled water calorimetry, which gives a direct determination of VO_{2max}, is time consuming and requires expensive equipment as well as highly trained technicians, and is further impracticable for use with large groups.[5, 6] Field methods on the other hand are much cheaper than the doubly labelled water method, and are faster to employ compared to both the cycle ergometer and treadmill test because one can handle multiple subjects at a time. Further, field methods could be coupled with the use of accelerometers to provide continuous information on body posture and activity allowing objective assessment of subjects' activity and levels of fitness. Accelerometers are electronic motion sensors with a major property of evoking a charge when deformed in a special direction. The magnitude of the resulting voltage is directly related to the extension of the deformation.[7] They are mainly worn at the chest level to detect the mechanical physical activity (PA) of the body and the minute-by-minute HR changes.

In the assessment of PF and CF, it is, for several decades now, an established fact that VO_{2max} is a critical physiological factor that plays an important role in the determination of physical work capacity and fitness under aerobic conditions.[8-10] It is superior to any other single test for evaluating physical work performance and is the most accurate physiological measure of cardio-respiratory fitness.[11, 12] Given the difficulties in the direct estimation of VO_{2max}, formulae have been developed to indirectly estimate it by subjecting individuals to any of the field non-

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invasive fitness tests. Thus, it is possible to establish a person's CF level. These tests include determination of VO_{2max} using the beep test score calculator developed from Ramsbottom tables[13] which are based on the highest level attained in the SRT protocol. It has an accuracy of within 0.1 ml/kg/min of directly determined VO_{2max} values.

It has an accepted criterion that VO_{2max} below 44 ml/kg/min in males aged 18-24 years is indicative of poor fitness and may lead to compromised health and fitness[14]. Accordingly, higher VO_{2max} is indicative of more favourable cardio-respiratory fitness. Previous studies have shown proportions of students with poor fitness-for-age of up to 10.4%. [15] A study on students of mean age 22.3±0.7 years and average body weight 56.8±11.9 kg in Thailand found that their average VO_{2max} was 38.1±8.6 ml/kg/min. When they were compared to the standard VO_{2max} values of the Thai general population, 39.4% were categorized in low health fitness group.[16]

In Kenya, no surveys on CF and/or PF amongst students have been carried out so far. However, there have been isolated studies involving other groups. One study showed that untrained Kenyan males (14.2±0.2 years) attained a mean VO_{2max} of 47 (44-51) ml/kg/min. Similarly aged male who exercised regularly attained VO_{2max} of 62 (58-71) ml/kg/min whereas runners in active training had VO_{2max} values of up to 68±1.4 ml/kg/min.[17] Another study comparing town and village dwellers[18] showed males of mean age 16.6 years from town setting attaining a mean VO_{2max} of 50 (45-60) ml/kg/min whereas their village counterparts attained 55 (37-63) ml/kg/min ($p<0.01$).

The 20 m SRT is a valid proxy for predicting laboratory VO_{2max} and is sufficiently reliable in healthy male adults[19]. It was designed[20] to be completed indoors using workloads (speed) lasting approximately one minute in each of its 21 levels. It is a progressive test and utilizes a pre-recorded sound signal to dictate running speed from 8.0 km/h in level one to a maximum of 18.5 km/h in level 21, by decreasing the interval between beeps. The incremental nature of the test ensures a gradual increase in work rate. A sequential lap scoring technique is used. Subjects run to exhaustion while maintaining cadence with the tape sound signal. The 20 m course is run on flat surfaces with a continuous multistage protocol. The present study assessed the various CF parameter markers amongst university students using a 20 m SRT.

Methods

The present study comprised 80 healthy male subjects aged between 18-25 years, randomly selected from Moi University, Kenya. They were drawn from the first and fourth years of study, with a target population slightly above 5,000 students. Ethical approval was granted by the Institutional Research Ethics Committee (IREC). The subjects were requested to give written informed consent before participating in the study. They also had to pass a full physical examination and be free of any cardio-respiratory or physical ailments. Further, because the study involved endurance exertion, a qualified first aider remained on standby throughout the SRT data collection protocol. Based on their reported past exercise history, they were categorized into regular, irregular and non-exercise groups for comparison purposes.

Protocol

The height and weight of subjects was measured using a heightometer and weighing scale (CAMRY, model BR9012) respectively. Baseline and abscissa BP were determined using a Mercurial Sphygmomanometer (EKRA Erkameter 3000, Germany). The baseline HR was measured by use of an ActITrainer™ (Actigraph, Pensacola, FL, USA) accelerometer. Participants were subjected to a 20 m SRT to the point they expressed subjective exhaustion or when they failed to maintain cadence with the beeps twice in a row, which signified exhaustion. Determination of VO_{2max} was based on the level from the protocol at which participants discontinued their run. The beep test score calculator developed from Ramsbottom published tables[13] was used to estimate VO_{2max}. The 20 m SRT, a valid proxy for predicting laboratory VO_{2max} is sufficiently reliable in healthy male adults[19]. It is normally administered indoors, is progressive in nature and utilizes pre-recorded sound signals to dictate running speed from 8.5 km/h in level one to a maximum of 18.5 km/h in level twenty one. This is achieved by decreasing the interval between beeps.

Statistical analysis

Data were analyzed using Stata version 10. Analysis of Variance was performed for equality of the various variables' means at the baseline, during and after the SRT protocol between the regular, irregular and non-exercise groups. Data were presented as means. Standard error of the mean (SEM) and standard deviation (SD) were considered where appropriate. p-value less than 0.05 were considered significant. Results are expressed as group mean ± standard deviation (and standard error of the mean where specified). Correlations are by Pearson's coefficient 'r'.

Results

The baseline descriptive bio-demographic characteristics of the 80 subjects in the current study are summarized in table 1. They were aged 21.4±1.8 years with an average height of 177.14±0.8 cm and weighing 64.96±0.81 kg. Their baseline measures of HR, RR, SBP and DBP were 72.86±0.59 beats/min, 15.26±0.11 breaths per minute, 113.5±0.85 mmhg and 72.55±0.76 mmhg respectively.

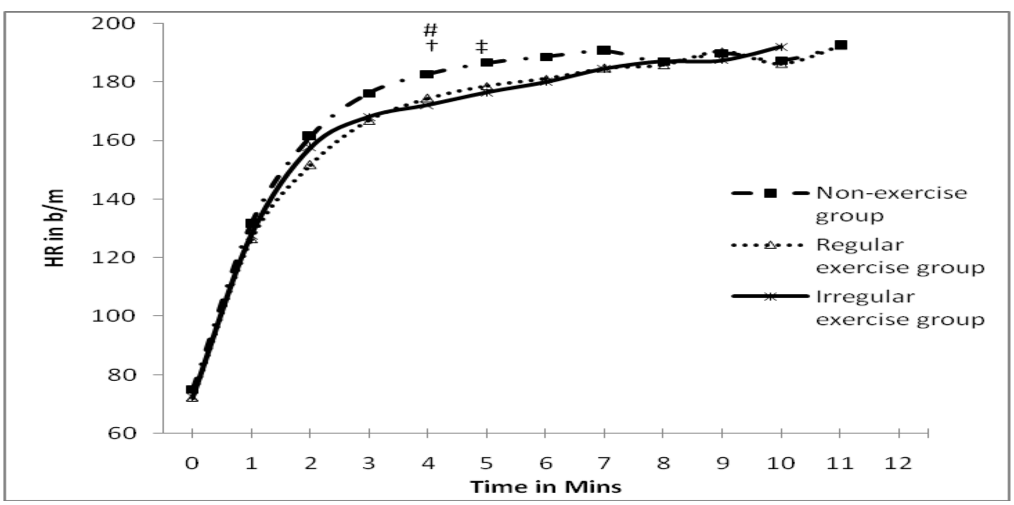
Table 1 : Bio-demographic data of subjects (Mean ± Standard Error (S.E)), n=80

Variable	Mean ± S.E
Age (years)	21.4 ±0.2
Height (cm)	177.14±0.8
Weight (kg)	64.96±0.81
BMI	20.83±0.26
Baseline HR	72.86±0.59
Baseline SBP	113.5±0.85
Baseline DBP	72.55±0.76
Baseline RR	15.26±0.11
TV	0.51±0.03
IRV	3.11±0.02
VC	4.74±0.02

BMI, body mass index; HR, heart rate in beats/min; SBP & DBP, systolic and diastolic blood pressure (BP) in mmHg; RR, respiratory rate; TV, tidal volume in litres; IRV, inspiratory reserve volume in litres; VC, vital capacity in litres.

Among the subjects, only 38 exercised in a regular manner (at least three one-hour sessions weekly) while 28 exercising irregularly. A total of 14 subjects did not exercise at all. Based on this criterion, the present study found that only in the 4th and 5th minute of the SRT protocol was there a difference in the HR means among the groups. Subjects with either regular or irregular exercise patterns attained significantly lower HR in the 4th minute compared with the non-exercise group (174.5±11.6 and 172.2±10.8 vs 182.8±6.8 b/m; p=0.04 and p=0.01 respectively). A similar trend was observed among the irregular exercise group after the 5th minute (176.5±10.1 vs 186.7±6.3 b/m; p=0.02).

There was no statistical difference in the HR means in the ranges outside the 4th and 5th minute of SRT between the three groups. Furthermore, no difference in HR was observed between subjects with regular and those with irregular exercise regimes. While no subject with reported exercise regimes (regardless of the regularity) had dropped from the SRT protocol after the 5th minute, 29% of the non-exercise subjects (n=14) had and continued to do so in higher proportions. This hampered further comparisons, and is illustrated in figure 1.



Symbols show HR differences between groups thus: #p=0.04 (non-exercise and regular exercise), †p=0.01 (non-exercise and irregular exercise), ‡p=0.02 (non-exercise and irregular exercise).

Figure 1: Heart rates during the running phase of the SRT protocol

On comparing either the SBP or the DBP between the three groups during the first five minutes of the abscissa, no statistical differences were observed (p values obtained were >0.05). The fall in SBP from exhaustion was similar in the three groups (p values >0.05). However, although no significant differences were observed in the rise in the DBP between the groups in abscissa, graphical representation demonstrated slight differences in the trend of DBP averages. Regular exercise subjects had the lowest DBP at exhaustion followed by the irregularly exercising, while the non-exercise subjects had the highest (58.58±15.0, 62.43±12.9 and 64.1±8.8 mmhg respectively). At the end of the first five minutes of rest, the two exercising groups had recovered closest to their baseline DBPs in comparison to the non-exercise group. This is typified in figure 2.

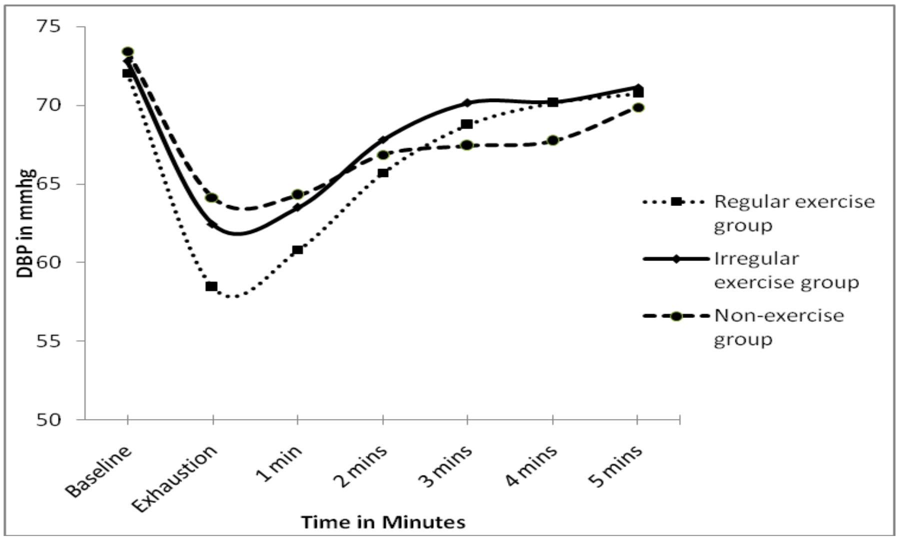


Figure 2.Diastolic blood pressure trends during the SRT protocol

Several predictors of VO_{2max} as a fitness marker were identified upon subjection of participants to the 20 m SRT. They included bio-demographic factors; year of study, age and weight, all yielding negative correlation thus: r=-0.40, p<0.01; r=-0.41, p<0.01 and r=-0.23, p<0.04, respectively, Other predictors included cardio-respiratory measurements of baseline HR and respiratory rate (RR) which had negative correlations with VO_{2max} (r=-0.25, p<0.02 and r=-0.49, p<0.001, respectively), tidal volume (TV), inspiratory reserve volume (IRV) and vital capacity (VC) all showing positive correlations (r=0.37, p<0.01, r=0.45, p<0.001 and r=0.49, p<0.001, respectively), The HR after the first and second minute run, after the fifth minute of rest as well as DBP at exhaustion and after the first minute of rest all showed significant negative correlations with VO_{2max} following the SRT protocol as shown in table 2.

Table 2: Correlation of various variables and VO_{2max} following 20 m SRT (n=80)

Variable	Pearson's 'r'	P value
Year of study	-0.40	<0.01
Age	-0.41	<0.01
Weight	-0.23	0.04
Baseline RR	-0.49	<0.001
TV	0.37	<0.01
IRV	0.45	<0.001
VC	0.49	<0.001
Baseline HR	-0.25	0.02
HR after 1 min run	-0.31	<0.01
HR after 2 min run	-0.30	0.01
HR after 5 min rest	-0.48	<0.001
DBP at exhaustion	-0.27	0.01
DBP after 1 min rest	-0.25	0.03

HR, heart rate; DBP, diastolic blood pressure. TV, tidal volume; IRV, inspiratory reserve volume; VC, vital capacity. All significant at p<0.05

The VO_{2max} for the regular exercise subjects was higher than for both the irregular ($p<0.01$) and the non-exercising ($p<0.001$) subjects at 45.11±4.69, 41.0±5.53 and 38.58±4.07 ml/kg/min in that order. There was no demonstrable difference in VO_{2max} between the irregular and non-exercise subjects.

Discussion

From the current study, it is clear that the more sedentary university students become, the higher their HRs rise during physical exertion. Subjects with reported involvement in exercise regimes, regardless of the regularity had significantly lower HRs after the 4th minute of the SRT protocol. These findings underscore the value of exercise even at suboptimal level.

Previous studies[21-23] have reported that subjects who exercise have less stiff blood vessels due to less fat deposits. This, together with increased skeletal muscle tone and sympathetic stimulation during exercise increase venous return by reducing peripheral resistance and thereby increasing stroke volume (SV) in order to meet the rising metabolic demands. Accordingly, non-exercising subjects are, on the other hand more likely to increase their cardiac output upon endurance exertion mainly by significantly raising their HR as opposed to a higher rise in SV. From the current study, it seems logical to suggest that it is only after about four minutes of physical exertion that differences in body adjustments to meet rising metabolic demands can be demonstrated among individuals with different exercise regimes. It is further plausible to suggest the same time period is crucial in the adjustment of HR as a determinant of cardiac output among non-exercising subjects compared to their exercising colleagues.

Further, sedentary university students portray a trend of higher DBP at exhaustion, and which returns to the pre-exertion levels more slowly. Previous studies suggest that for most healthy young men, there is enhanced early DBP decay during and immediately following exercise which allows SV to increase despite an increase in diastolic viscoelastic resistance and chamber stiffness[23]. This was not the case amongst subjects who did not report involvement in any exercise pattern. Since PA helps maintain low lipid levels which regulate BP by facilitating blood vessel elasticity[1-3], it appears that the less active subjects of the current study are likely to have higher lipid deposition in their blood vessels yielding higher DBP immediately after exhaustion due to reduced vessel elasticity. While this would be more expected amongst the elderly, the fairly young sedentary students in the current study portray the trend, implying poorer fitness.

That both the irregularly and non-exercising subjects attained VO_{2max} well below the expected average of 44 ml/kg/min for their age[14] suggests compromised fitness in these groups. Previous studies[24, 25] demonstrated a similar pattern of lower VO_{2max} among the more sedentary individuals. It appears that it is only with regular exercise regimes that university-attending individuals may attain a minimum-for-age VO_{2max}, as has previously been suggested[18]. It also appears that VO_{2max} is a more complete indicator of the fitness differences among subjects given that HR was affected by individuals dropping from the SRT at different levels, and the BP measures did not yield strict statistical differences.

Various variables correlated with VO_{2max} as an indicator of PF. The year of study, age and weight correlated negatively with VO_{2max}. With increasing age, studies have noted a decline in exercise participation[26, 27], otherwise necessary for improved fitness primarily by enhancing maximal oxygen uptake among individuals[24]. Respiratory variables: TV, IRV and VC correlated positively with VO_{2max}. Accordingly, students with higher lung volumes and capacities were more likely to be physically fitt compared to their colleagues with lower lung functions. Previous studies have shown that lung function parameters have a positive relationship with regular exercise, and that regular exercise increases pulmonary capacity[28, 29]. Present results however found that baseline RR had a negative correlation with VO_{2max}, such that subjects with higher baseline RR were less fitter compared to their colleagues with lower values. It may be possible that the higher RR may compromise VO_{2max} by reducing arterial oxygen partial pressure due to the shorter gaseous exchange time at the respiratory membrane. This may be so because even though a large safety factor exists (time red blood cells remain in alveolar capillaries), the alveolar oxygen tension is reduced by increased RR so that only a smaller amount of oxygen is available to diffuse and be bound to haemoglobin.

While previously the resting BP had been identified as a predictor for VO_{2max}[30], the present study found, instead, other cardiovascular variables as significant negative predictors among university students. These included the baseline HR, HR in the first two minutes of exercise and after five completed minutes during the abscissa. The DBP within the first minute of exhaustion is also a predictor. Students whose HRs are higher immediately following exertion achieve less VO_{2max} compared to their colleagues with lower rates and are therefore less fitter. Present results however did not demonstrate a significant correlation between SBP and VO_{2max}. Thus, students whose DBP at exhaustion was lower were considered more physically fit, and with better CF. Previous studies[21, 31] have only demonstrated that DBP decays during and immediately following exercise and that there is a progressive increase in SBP widening the pulse pressure which allows SV to increase, but have not shown how this relates to fitness. Current findings suggest that the more the DBP decay in an individual, the higher the VO_{2max} they are likely to attain and the physically fitter they are.

Limitations in the current study included fact that the 20m SRT has greater variability compared to the more direct doubly labelled water method[4], and that the shuttle run could not separate performance defined by motivation of participating in the field test from that of actual fitness. However, with an accuracy of within 0.1 ml/kg/min to the directly determined VO_{2max}[13, 19, 20], the findings of the current study are yet valid and reliable.

Conclusion

There is strong evidence of the need to encourage exercise regimes amongst university students, even if with less regard to regularity. Further, emphasis for regular exercise should be given for those in higher study years, the older and those with evidence of increasing weight. Subjects with higher baseline HR, those whose HRs remain higher within two minutes of SRT and after five minutes of rest, and those with higher DBP immediately following exhaustion from physical exertion should be encouraged to exercise more regularly to increase their VO_{2max} and therefore raise their fitness levels.

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