Journal of Advances in Medicine and Medical Research

23(11): 1-9, 2017; Article no.JAMMR.24077
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

Effect of Submaximal Isometric Exercise on the Relationship between Body Mass Index (BMI) and Blood Pressure (BP)

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AON and OMO designed the study, wrote the protocol and wrote the first draft of the manuscript. Author AAA managed the literature searches, analyses of the study and performed the spectroscopy analysis. Authors JCI and CPA managed the experimental process and identified the species of plant. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2017/24077
Editor(s):
(1) Ricardo Forastiero, Professor of Physiology and Internal Medicine, Haematology, Favaloro University, Argentina.
Reviewers:
(1) Jerzy Beltowski, Medical University, Poland.
(2) Fethi Ben Slama, National Institute of Public Health, Tunisia.
Complete Peer review History: http://www.sciencedomain.org/review-history/21069

Original Research Article

Received 2nd January 2016
Accepted 14th December 2016
Published 20th September 2017

ABSTRACT

One of the major determinants of desirable body weights is the body mass index (BMI). In humans, BMI is the ratio of body weight (in kg) to height (in meters square). Helpful to clinicians in estimating average healthy weight and nutritional status of their clients, findings have reported BMI to be dependent on several factors as; genetics, exercise, blood pressure (BP), peripheral arterial blood flow, dietetics, basal metabolic rates (BMR), etc. The goal of this study was to find in men, the effect that sub-maximal isometric exercise has on the relationship between BMI and peripheral arterial blood flow. To achieve this, 400 humans were ethically recruited from Irrua Specialist Teaching hospital, Irrua, Edo State of Nigeria. By means of bidirectional Doppler, Velocity of arterial blood flow (in their upper extremities-brachial arteries) was determined and recorded

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against values obtained for measured BMI. Subjects were then sorted by age and grouped based on values from arterial flow as; 120 normotensive normal BMI (120-NTNBMI), 120 normotensive high BMI (120-NTHBMI), 80 hypertensive normal BMI (80-HTNBMI), and 80 hypertensive high BMI (80-HTHBMI). Using ANOVA and student t-test, statistical measures of deviation/central tendencies were conducted on obtained data, p-values less than 0.05 were takes as statistically significant. Study found upon analysis, no significant relationship between arterial blood flow of normotensives with normal or high BMI after exercise. Pearson Product moment correlation returned positive correlation between normortensive normal BMI and peripheral arterial blood flow.

Keywords: Body mass index (BMI); blood pressure (BP); sub-maximal; isometric exercise; normotensive BMI; hypertensive BMI.

1. INTRODUCTION

The effect of submaximal isometric exercise on the relationship between BMI, hypertension, and peripheral arterial blood flow is yet to be clearly understood. In spite of the major advances in the recognition and control of hypertension and raised blood pressure, high BMI remains a major risk factor in the development of coronary artery, cerebrovascular, and renal disease [1,2]. It places one at greater risk of developing chronic diseases like diabetes mellitus, hypertension, heart disease, and even cancer [3,4].

With several implicated indices of health risk, the body mass index (BMI) is the mathematical ratio of weight (in kilogram) to height (in meters square) that can be linked with body composition or body fat percentage. According to the world health organisation, People with a BMI of 25 to 29.9 are considered overweight, while those with a BMI of 30+ are considered obesed [5]. The relationship between BMI and mortality has reportedly shown to vary with sex, age, cohort effects, socioeconomic status and ethnic background [6]. A linear relationship is commonly observed between cardiovascular disease (CVD) mortality and increasing BMI [7]. It is however believed that a high BMI assumes a higher percentage of body fat, which makes it an unreliable indicator of health as a highly muscled individual who is very fit and healthy may present with heavy body weight as a result of increased muscle mass. Experimental evidence have shown that cerebral flow velocities for example decrease with increasing body mass and age, and that male sex is associated with lower blood flow velocity (BFV) especially among stroke patients. Higher BMI is also associated with increased cerebrovascular resistance (CVR) during supine rest and orthostatic stress [8].

Overtime, Health practitioners have managed innumerable cases of Elevated blood pressure through lifestyle modifications like low-salt diet, maintenance of ideal weight, aerobic exercise and a diet rich in fruits, vegetables, plant fibres, and the mineral potassium.

While data from studies on the effect of exercise on short-term weight loss are contradictory, available findings posit, that regular exercise is the single best predictor for which long-term weight control can be achieving. It is also believed that regular exercise (RE) can improve some of the medical conditions associated with high BMI, including elevated blood cholesterol, hypertension, and diabetes mellitus. Hence, its recommendations in recent time as a way for complement aerobic training programme, especially in aging population. However, recent evidence indicates that RE may cause increased arterial stiffness in young, healthy normotensive individuals [9,10].

Whilst the prevalence of arterial hypertension and cardiovascular diseases are yet to be known in Nigeria, The prevalence of overweight individuals in Nigeria is of epidemic proportions, ranging from 20.3%–35.1%, while the prevalence of obesity ranges from 8.1%–22.2% [11,12,13].

1.1 Aim of Study

This study aimed at finding in humans, the effect that sub-maximal isometric exercise poses on the relationship between BMI and BP. Specifically, study was designed to find the effect of moderate exercises on the relationship between BMI and raised blood pressure. Study also attempted to find the effect of age on exercise-induced change in normal and high states of BMI.

2. METHODOLOGY

2.1 Resources and Sources

2.1.1 Humans

Using the random sampling technique, a total of four hundred humans (400) between ages 20 years and 68 years were recruited from Irrua Specialist Teaching hospital, Irrua, in Esan Central Local Government Area of Edo State for this exercise. In Nigeria state of Edo, Esan Central is a 506 km² local government area with population of about 202,712 (NPC, 2006). Edo State is a $16{,}842/km^2$ area of land that approximately lies between Longitude $5^0 00$ and $6^0 . 45'$ East and Latitude $5^0 00$ and $6^0 . 30'$ North (National gazette, 2007). All 400 male participants were then categorised into 160 hypertensive and 240 normotensives as found.

The decision to sample 400 humans was informed by the Slovin's statistical relation:

$$SS = \frac{Z^2 P \times (1 - P)}{C^2}$$

Where →

SS = Sample Size
Z = Confidence level as z-score (95% = 1.96 from z-table)
P = Population proportion variance. (Maximal at 0.5 from binomial distribution table)
C = Confidence interval or margin of error (0.05).

The above relation returned a minimum of 384 samples for a population size as 202,712, the town under study.

2.1.2 Questionnaire

With the aid of a carefully structured self-administered Questionnaire, relevant data relating to subjects' Age, health status, socioeconomic status, Drugs/Duration of usage, Time of stopping Therapy, Weight, Height, and Hospital was obtain. Those who met inclusion and exclusion criteria below were enrolled into the study with their consents.

2.1.3 Facilities for determining BMI

- Weighing Balance (in kilogram calibre).
- Tape Rule in meters and inches on graduated wall.
- Strong flat surface to step on.

2.1.4 Sphygmomanometer

Standard mercury in glass sphygmomanometer of the aneroid specification was obtained for non-invasive measurement of BP.

2.2 Protocol

Ethical Permission for the study was sourced from the Ethical Committee of the Irrua Specialist Teaching Hospital, Irrua, informal consent from the subjects of study was obtained as well.

2.3 Inclusion Criteria

In hypertensive, available findings assert that regular exercise, gender, specifically males of age brackets 20-68+years, and the use of Non-vasodilator drugs are intimately linked (Casey et al., 2007). Based on this, Age (20-50+years), Gender (Male), and Drugs (Non-vasodilator) formed the bases for choosing eligible subjects in the study.

2.4 Exclusion Criteria

Subjects who had Diabetes Mellitus (DM), Peripheral vascular disease (PVD), Hyperlipidaemia, and/or Osteoarthritis where exempted from the study. Individuals under vasodilators were also excluded for reason that these factors may negatively influence BMI/ exercise correlations in hypertensive subjects.

2.5 Procedure

Firstly, History, Clinical examinations and lab investigations were carried out on subjects. This was necessary to affirm their health status, plus ascertain their eligibility to participate in the study based on above selection criteria. By means of a standard mercury sphygmomanometer, cardiovascular measurements of Pulse rate, systolic and diastolic blood pressure (BP) was obtained at rest state for each subject. Next, BP measurement was respectively repeated and recorded in 10 and 20 minutes, following the administration of submaximal exercise to participants. Based on systolic and diastolic values obtained (SBP and DBP), subjects were then classified as either hypertensive (SBP and DBP ≥ 140 and 90 mm Hg respectively) or normotensive (SBP and DBP < 140 and 90 mm Hg respectively). The decision to use above values as grouping standard was informed by recommendations of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure [14,5]. Worth mentioning is that this procedure was exclusively carried out by qualified nurses and physicians.

2.6 Measuring Maximum Exercise Capacity

Using the Ergometer, maximum Exercise Capacity for each subject was achieved by means of a progressive exercise test. The procedure involved setting the machine for a work load increments of 15 Watts every 3 min at cycle velocity of 60 rotations per minute (rpm). This was in accordance with the machine's manufacturer guide as studied (Medifit 400L, Medical Fitness Equipment, Maarn, Netherlands). Ergometer was calibrated by hanging a known weight of 5kg into the groove of the calibration bar which has been machined at a distance of 66cm from the center of the output shaft, the resulting torque was computed as:

> Torque = 0.66 x 5 = 3.3 kg*m, which would appear on the display set to show torque values. Torque is the ability to overcome resistance. That is the measurement of the ability of rotating gear or shaft to overcome turning resistance.

2.7 Measuring the BMI

BMI was based on a weight-to-height ratio in kg/m2 that does not distinguish between muscle and fat.

2.8 Statistical Analysis

Using SPSS (version 20) software, Evaluation of collected data for statistical significance was obtained with ANOVA and Students't-test (Depending on data). In each case, coefficient of correlated data was obtained with the Pearson product moment correlation. P-values less than 0.05 were taken to be statistically significant.

3. RESULTS AND DISCUSSION

Figs. 2.1 and 2.2 show the effect of exercise-induced change in blood pressure on normal and high BMI with age respectively. As observed, systolic blood pressure of normotensive subjects who had high BMI in age groups 20-30 years and 41-50 years was not altered after moderate exercise. However, the systolic blood pressure of normotensive subject who had high BMI with age group within 31-40 years was significantly decreased as $p < 0.05$ compared to the resting state.

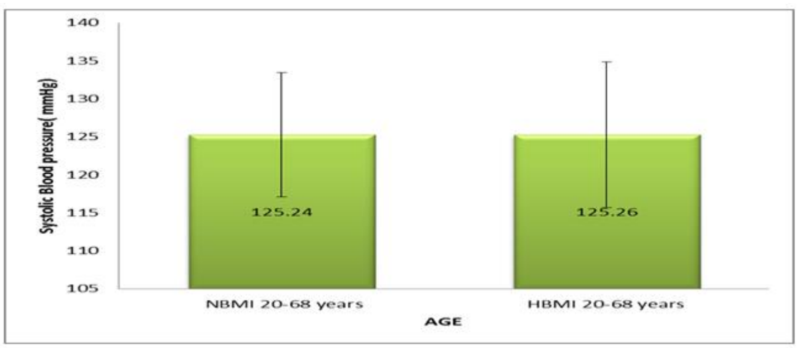

Fig. 2.1. Showing systolic blood pressure of subjects with normal and high BMI at rest

For each group (NBMI and HBMI), ANOVA returned 125.24 and 125.26; which were found critical for f < f-crit. at P < 0.05. Thus, mean Systolic blood pressure of subjects with high and normal BMI were not significantly different

Fig. 2.2. Diastolic blood pressure of subjects with normal and high BMI at rest

For each group (NBMI and HBMI), ANOVA returned 82.73 and 81.18; which *were found critical for f < f-crit. at P < 0.05. Thus, mean Diastolic blood pressure of subjects with high and normal BMI were not significantly different*

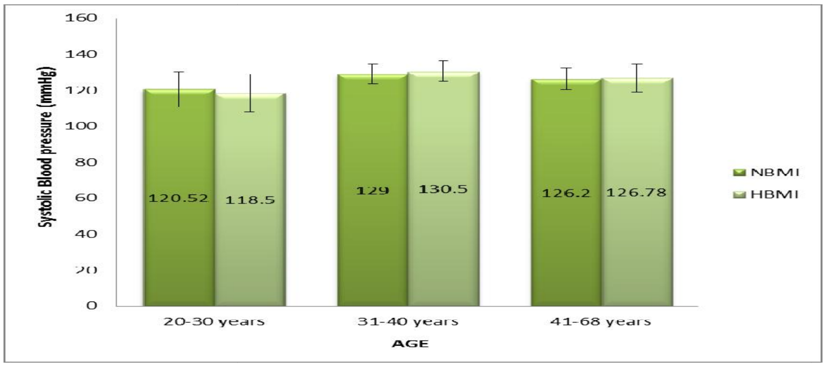

Fig. 2.3. Systolic blood pressure of subjects with normal and high BMI at rest based on age
Here, ANOVA proved insignificant as mean systolic blood pressure of subjects with high and normal BMI, irrespective of the age group, were not significantly different

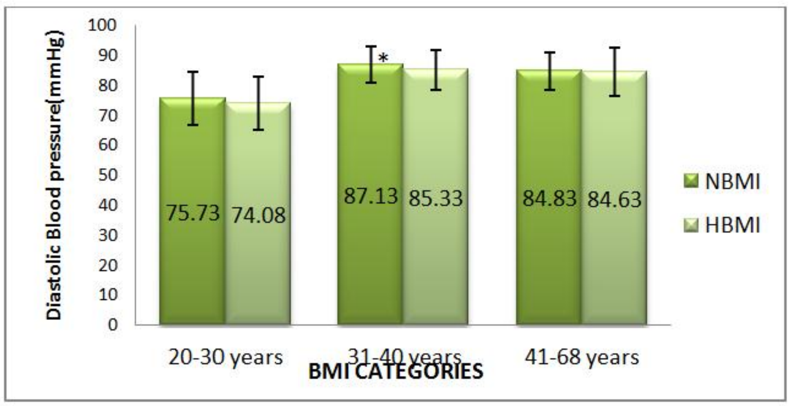

Fig. 2.4. Diastolic blood pressure of subjects with normal and high BMI at rest based on age
Here, mean diastolic blood pressure of subjects between 20-30 years or 41-68 years of age were similar but those of normotensive subjects with high BMI in 31-40 years age bracket was significantly lower as p<0.05, compared to subjects with normal BMI

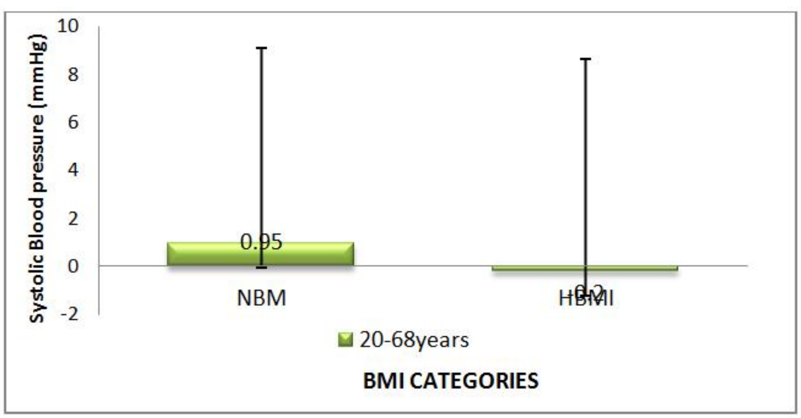

Fig. 2.5. Exercise- induced changes in systolic blood pressure in subjects with high and normal BMI
Mean systolic blood pressure of subjects with high BMI was not significantly different

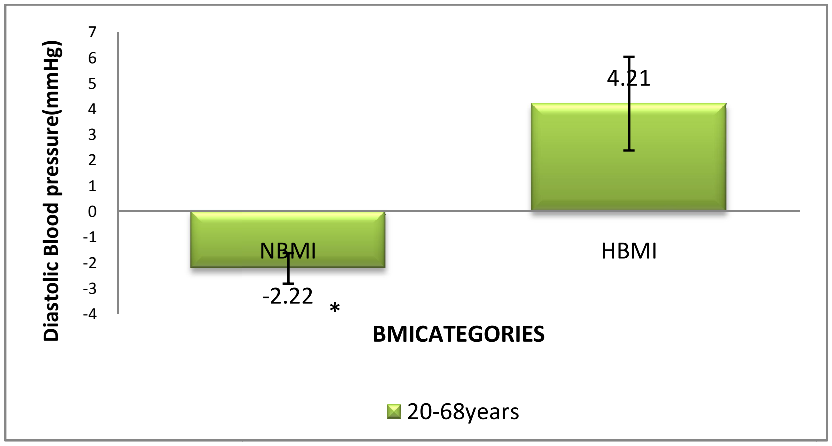

Fig. 2.6. Exercise- induced change in diastolic blood pressure in subjects with high and normal BMI

Diastolic blood pressure of subjects with normal BMI was significantly lower as p< 0.05 compared with the values for high BMI after exercise

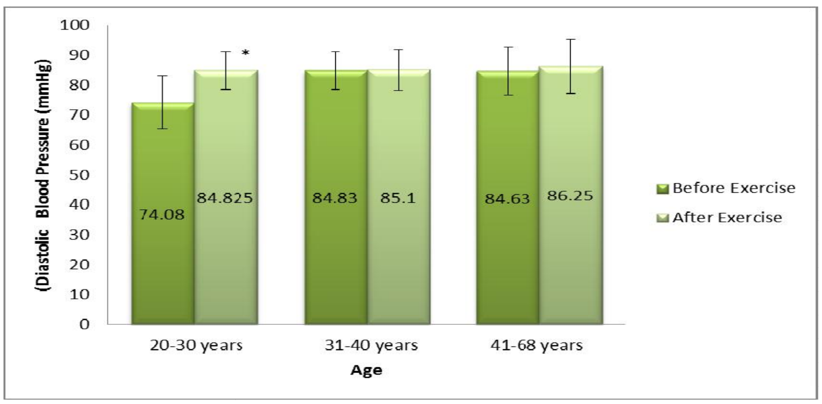

Fig. 2.7. Diastolic blood pressure of subjects with high BMI in different age groups; before and after moderate exercise

The effect of exercise on mean diastolic blood pressure in 20-30 years age group was significant (p<0.05), increasing though within normal BP range as compared with other age categories

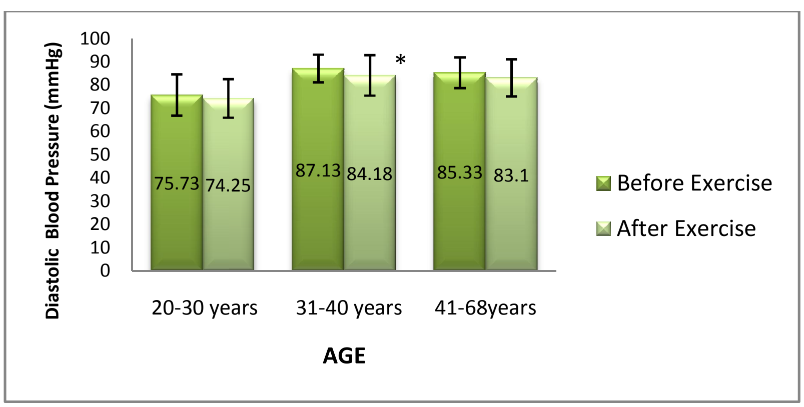

Fig. 2.8. Diastolic blood pressure of subjects with normal BMI in different age groups; before and after moderate exercise

At p<0.05, Exercise significantly decreased diastolic blood pressure of age group 31-40 years compared to other age categories

Table 2.1. Relationship between arterial blood flow and BMI in normotensive Subjects before and after moderate exercise

Subjects (Normotensive)	BMI	Arterial blood flow (ABF)	Correlation	P-value	Remark
At rest	25.98 ± 4.84	23.50 ± 5.06*	0.048	0.462	Not significant
After exercise	25.98 ± 4.84	27.70 ±4.46	0.098	0.150	Not significant

N=120

There was no significant relationship between arterial blood flow and BMI for normotensives before and after exercise

Table 2.2. Relationships between arterial blood flow and BMI in normotensives with high or normal BMI after moderate exercise

Subjects	BMI	Arterial blood flow (ABF)	Correlation	P-value	Remark
Normal BMI	22.06 ± 2.06	27.53± 4.56	0.060	0.516	Not significant
High BMI	29.91 ± 3.44	27.87 ±4.37	0.142	0.122	Not significant

Table 2.3. Effect of age on BMI and arterial blood flow of normotensives

Age range	Arterial blood flow of subjects with normal BMI	Arterial blood flow of subjects with high BMI
20-30 years	23.08± 6.02	23.40 ± 6.02
31-40 years	22.03 ± 3.88	21.29±4.48
41-68 years	25.71±4.07+	25.49±4.15*

**p < 0.05, compared with other high BMI values; n = 40*

+ p < 0.05, compared with other normal BMI values; n = 40

Also, it was observed that irrespective of the age group, hypertensive subjects with high BMI, who were exposed to moderate exercise showed significant decrease in their systolic blood pressure values. In an overall review [15,16] suggest that isometric or resistance exercise results in either no change or small reductions in resting systolic and diastolic BP and, more important, does not appear to raise it, as it was feared in the past.

Also, In an updated Medline search reviewed Kelley and co-workers, 17 hypertensive patients aged 60 to 80 years from 2000 to 2009 participated in isometric exercises by performing 4 isometric contractions at 30% MVC for 2 minutes 3 times per week for 10 weeks (Taylor et al, 2003). Result suggested that isometric exercise is becoming a useful tool for this condition. At the end of the exercise training, there was a significant reduction in resting systolic BP by 19 mm Hg (*P*<.001) and mean BP by 11 mm Hg (*P*<.009) and a 7-mm Hg reduction in resting diastolic BP (*P*=not significant). The resting heart rate was not changed, but the isometric exercise was associated with a trend toward lower low-frequency/high-frequency ratio for heart rate, although not statistically significant for the group. Recent studies and a meta-analysis also show significant additional BP-lowering effects of isometric exercise to antihypertensive treatment ranging from 11.0 mm Hg to 14.8 mm Hg for systolic BP and 3.3 mm Hg to 10.3 mm Hg for diastolic BP [13,16,17].

The overall review [17] suggest that isometric or resistance exercise results in either no change or small reductions in resting systolic and diastolic BP. The report of this finding supports those asserted in McGowan's report. Thus, it appears that vasodilation is preserved during mild to moderate exercise as was observed in the age category of 31-40 years. Endothelial vasodilation is believed to play a smaller role in blood flow control during exercise and possibly, endothelial impairments are disguised by compensatory vascular control mechanisms (Magdy et al, 2008). It was further stressed that impaired nitric oxide dilation may be compensated by an up-regulation of endothelium-derived hyperpolarizing factor (EDHF) (Feletou and Vanhoutte, 2006). If this occurs, it may be plausible that blood flow impairments could be seen when exercise intensity is studied at workloads above 12 kg, where limitations in compensatory mechanisms may occur as was observed in the age category of 31-40 years.

3.1 Societal Advantage of Study

Records in public and private hospitals in Irrua and Ekpoma environ, provide evidence that high BMI and hypertension are major health burden of the area. This therefore suggests the need for scientific data to objectively guide clinicians and other extension health workers in terms of management of their patients. This study will therefore provide the necessary scientific basis for the management and treatment of hypertension cases that are complicated with high BMI and the associated circulatory disorders especially in relation to exercise.

4. CONCLUSION

Within the ambient of vulnerability to possible human, logical, or analytical errors, this study has shown that systolic blood pressure of normotensive subjects who had high BMI in age groups 20-30 years and 41-50 years was not altered after moderate exercise. Thus, providing some scientific basis for additional BP-lowering effects of isometric exercise to antihypertensive treatment of cardiovascular diseases complicated with high BMI and hypertension especially in relation to peripheral arterial blood flow in men.

5. RECOMMENDATIONS

It is recommended that further studies be done to ascertain if a relationship exists between submaximal isometric exercise, BMI, and peripheral arterial blood flow; as this may deepen the scientific based knowledge for the management and treatment of hypertensives with high BMI complications.

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard or university standard, written approval of Ethics committee has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/21069