Relation between derived cardiovascular indices, body surface area, blood pressure/heart rate recovery among active and inactive Nigerian student

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Research Article

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Abstract

BACKGROUND

The ease in the computation of derived cardiovascular indices such as mean arterial pressure [MAP], rate pressure product [RPP] and pulse pressure [PP]), make them attractive for use in making clinical decision for patient management in resource deprived environment. This study sought to determine the relationship between these indices and heart rate/blood pressure drops during recovery state among physically active and inactive individuals following submaximal exercise.

RESULTS

This quasi-experimental study conveniently sampled 105 apparently healthy male subjects age 18-35 years of the University of Maiduguri. Inter-group categorization was executed by IPAQ. The derived indices were calculated using heart rate and blood pressure measurement while the body surface area (BSA) was determined using height and weight. The subjects were subjected to a submaximal exercise test using a bicycle ergometer. Data analysis include; descriptive statistic, Pearson correlation, student t-test, analysis of covariance and multiple linear regression. The data was analyse using SPSS version 25.0 at significance of $p<0.05$. The mean BSA and resting-PP, MAP and RPP were 1.84±0.16 m^2, 41.23±7.57 mmHg, 85.92±9 mmHg and 8266.45±1404.05 respectively. The resting-RPP of the physically inactive subjects was significantly higher than that of the active (8742.71±1496.31 vs 7790.18±1131.59, p=0.00) however, the active subject had a higher resting-MAP than the inactive (87.91±7.98 Vs 83.93±9.59, p=0.03). The relationship between the RPP and the Absolute/percent recovery HR was r=-0.23, p=0.02/r=-0.34, p=0.00. The relationship between the PP and absolute recovery SBP was r=0.22, p= 0.03. The relationship found between the MAP and absolute recovery SBP was (r= 0.33, p= 0.00). The best negative predictor negative predictor recovery HR was the RPP while the MAP was the best positive predictor of recovery HR and SBP.

CONCLUSIONS

Overall, the physically active subjects coped better during the exercise than their inactive counterpart because of lower cardiac work and better blood perfusion to vital body organs. An inverse relationship was found between the RPP and absolute/percent recovery HR at one-minute post exercise while a positive relationship was found between the PP and absolute drop in SBP/percent drop in DBP one-minute post exercise. The best predictor of recovery HR and blood pressure was the RPP.

Background

The derived cardiovascular parameters are important clinical tools that compliments direct measures such as heart rate and blood pressures in assessing cardiovascular system status and response to stimulus. These parameters including; pulse pressure [PP], mean arterial pressure [MAP], cardiac index [CI], and rate-pressure product [RPP]. They are important cardiovascular indices that are derived and are easily computed, making it attractive for use in decision making for care in resource challenged environment, such as obtainable in resource deprived countries. The average pressure in the artery obtained in one cardiac cycle is labelled the MAP, it is an indication of blood perfusion and a function of cardiac output [CO], central venous pressure [CVP] and systemic vascular resistance [SVR] , and other factors [diameter of blood vessel, nitric oxide [NO], endothelin, and Baroreceptor reflex] [1]. The MAP is calculated using the equation; MAP = [CO. SVR] +CVP or P_{dias}+1/3 [P_{sys} - P_{dias}] i.e. pressure at diastole plus a third of the difference between pressure at systole and diastole [1].

An elevated MAP (average value at 60 mmHg), trigger an increase in the shearing forces on the wall of endothelial cells lining the blood vessel which causes NO and other vasodilation compounds to be synthesized with the resultant action of relaxation (vasodilation) of smooth muscle vasculature. On the reverse, a decrease in MAP triggers the release of endothelin with opposite effect to NO, leading to vasoconstriction [2]. The MAP is also regulated by the autonomic nervous system through the baroreceptor reflex. For example, communication to the solitary nucleus, situated on the dorsolateral area of medulla oblongata of the brainstem by baroreceptors determines the tone (whether parasympathetic or sympathetic) to lower or increase MAP according to the need of the body [3]. On the reverse side, increase in baroreceptor stimulation with associated elevation in MAP causes the solitary nucleus to decrease sympathetic output and increase parasympathetic output with subsequent drop in MAP and resultant reduction in CO.

Likewise, a decrease in the activities of the baroreceptors with associated decrease in MAP causes the solitary nucleus to reduce parasympathetic tone in favour of sympathetic tone which result in an increase in SVR and CO, with the MAP effectively increased [4]. The sympathetic tone is also upregulated during events such as, exercise, vascular trauma, emotional stress and psychological stress. Furthermore, CO calculated by multiplying the SV and HR, is of physiologic importance to the overall organism metabolism [5], and reflects the ability of the body to adjust to metabolism and workload increase. The PP correlate well with the SV and is calculated using the equation, $P_{ulse} = P_{sys} - P_{dias\ i.e.}$ the change in systolic and diastolic pressure [1].

An index often used to determine the uptake of oxygen by the myocardium is labelled the RPP, and is simply calculated as HR_{rest} multiply by the SBP [1]. It is also used to determine the energy needed for the proper functioning of the heart and how this energy is expended. The CI is use to show the relationship between how well a person's heart is functioning and the body surface area [BSA], it also used to show how the CO and BSA are correlated [6, 7, 8]. The formulae used to calculate the CI is;

, [9, 10, 8], as shown in the formulae; BSA, body surface area; SV, stroke volume; CO, cardiac output; CI, cardiac index; HR, heart rate and unit measurement L/min/m^2 i.e. litre per minutes per metre square. Measurement of CI between 2.6 – 4.2 L/min /m^2 at baseline have been reported to be normal [11], and values below and above this range are said to be abnormal. For example, a patient in cardiogenic shock may have value below 1.8L/min/m^2. The CI is therefore an essential clinical reading used to assess patients with a heart problem, seriously sick patients on intensive care and those under the influence of anaesthesia.

More so, using the measurement from height and weight the BSA [metre squared; m^2] is calculated using, "DuBois' equation: BSA in meter = $[\text{wt in kg}]^{0.425} \times [\text{ht in cm}]^{0.725} \times 0.007184$" [12].

The Recovery Heart has also been used to determine cardiovascular fitness and the chances of a person dying within one year. For instance, some researchers have reported that "a delay drop in the HR a minute after stopping an exercise is a strong independent predictor of death within a year" [13, 14]. Similarly, recovery systolic blood pressure has also been utilized by clinicians as an importance tool in diagnosing abnormality in the cardiovascular system [13, 15, 14].

Non-invasive method used to estimate the derived cardiovascular parameter have been reported in literatures. For example, José et al. [16], used impedance cardiograph to determine the SV, MAP, CO and PP. On the other hand, Carlsson et al. [5] used cardiovascular magnetic resonance (similar to doppler measurement and bio-impedance), to assess the derived cardiovascular parameter such as CI and SV. The M-mode echocardiograms and Teichholz correction of the cube formula have been utilized to assess SV, interventricular septal/posterior wall thickness and end diastolic/systolic volume. Measurement of the SV and LV chamber volumes estimated by M-mode and Teichholz correction method have been shown to have a good correlation with doppler-echocardiographic volume measurement and other invasive techniques [17, 18, 19, 20]. These non-invasive techniques and other invasive method, although reliable, require that the user should have an advanced knowledge on how to use them and are tedious, time consuming, risky and expensive procedures. Determination of MAP, PP and RPP by calculation are also reliable, simple, reproducible, and less time-consuming method similar to the above mentioned non-invasive and invasive tedious techniques. For example, assessment of the RPP is a readily available non-invasive means of ascertaining the VO_2max, it is reliable, simple and reproducible, serving similar purpose as expensive non-invasive and invasive method [21].

Previous studies on some derived indices are available in literatures. For example, Carlsson et al. [5] report that the CI of the healthy and athletic subject was no different at rest however, patients with congestive heart failure and had lower CI at rest. Giovanni de Simone et al. [22], reported that with elevating size of body the CO and SV rate of change was higher in adults compared to children. While Shahraki et al. [23], found that the MAP/PP at rest, during exercise and after exercise was more in athletic than in the non-athletic female subject and our larger study that reported a higher drop in both the HR and blood pressure recovery in the physically active young adults than their sedentary counterpart following a bout of exercise [24].

It is a general belief that the use of derived indices to assess cardiovascular status is not common among clinicians. As most practitioners in low resource countries such as Nigeria often lament the absence of state-of-the-art instrumentations, the use of derived indices that are easily computed is not widespread. Furthermore, however, the relationship between MAP, PP, RPP to BSA and the rate of drops in blood pressure and HR after the removal of exercise stimulus is unexplored. This report is part of a larger study that compares the responses of physically active and physically inactive young adults [24]. Only the data on the derived indices and recovery cardiovascular parameters of HR and SBP are presented in this report. The primary purpose of this report is to determine the relationship between these indices and HR/blood pressure drops in recovery state among physically active and inactive individuals following submaximal exercise. The secondary purpose is to elucidate on some derived cardiovascular indices of MAP, PP, RPP and BSA and their clinical implications.

Results

The subject's physical characteristics

The physically characteristic such the age, height, weight, blood pressure, HR, recovery blood pressure and HR were part of a larger study reported elsewhere [24]. One hundred and two (102) apparently healthy "physically active" and inactive students of age rage 18-35 participated in this study. Twenty-three of the subjects (22.5%) were of age range between 18-22 years, 53.9% (n=55) were of age range 23-27 years, and 23.5% (n=24) were of age range 28-32 years. About 12.7% (n=13) were under weight, 75.5% (n=77) were normal weight, 9.8% (n=10) were overweight and 2% (n=2) were obese. The mean ± SD of the BSA was 1.84±0.16 m^2 (range; 1.5-2.33), while that the mean PP was 41.23±7.57 mmHg (range; 25-61). Also, the mean MAP and RPP were 85.92±9 mmHg (rang; 67-108 mmHg) and 8266.45±1404.05 (range; 5411.24-12401.01) respectively.

Comparison of derived Cardiovascular indices and body surface area among Physically active and inactive subject

There was no significant difference (p=0.36) between the BSA of the physically active (1.86±0.16 m^2) and inactive (1.83±0.16 m^2) subject albeit, the BSA of the physical active was higher than their inactive counterparts. Similar findings were seen between the resting PP of physical active and inactive subject (41.59±7.88 mmHg, p=-0.68 Vs 40.87±7.30 mmHg, p=0.63). The resting RPP of the physically inactive (8742.71±1496.31) subjects, was significantly (p=0.00) higher than that of active (7790.18±1131.59) subjects, suggestive perhaps that the physically active group are coping better with the exercise with relatively lower cardiac work output compared to the inactive group. The resting MAP of the physically active subject was significantly higher than that of their inactive counterpart (87.91±7.98 Vs 83.93±9.59, p=0.03), suggesting that the perfusion to tissues is better for the active group than the inactive group, results for PP, MAP and RPP at the peak of exercise and at 1, 3 and 5-minutes post exercise were also presented in Table [1].

Relationship between body surface area, derived cardiovascular indices and Absolute/ percentage recovery heart rate/ blood pressure

Table 2 presents, a negative significant but tenuous relationship between the RPP and the Absolute recovery Heart rate at 1 minute (r=-0.23*, p=0.02) and percent recovery HR at 1-minutes after exercise (r=-0.34**, p=0.00). There was also a tenuous positive significant relationship between the PP and absolute recovery SBP (r=0.22*, p= 0.03) and percent recovery DBP (r=0.20*, p=0.04) at 1-mute post exercise. There was also tenuous positive significant relationship between the MAP (r= 0.33** p= 0.00) and percent recovery SBP (0.28**, p=0.00). The BSA showed no significant relationship with Absolute recovery HR/percent recovery HR, Absolute recovery SBP/percent recovery SBP and absolute recovery DBP/percent recovery DBP as show in table [2].

In table 3, there was again a tenuous negative significant relationship between the RPP and absolute recovery HR3/percent recovery HR3 (r=-0.20, p=0.04 Vs r=-0.33, p=0.00) at 3 minutes post exercise. Interestingly, there was no significant relation between the PP and the recovery BP and HR at 3 minutes post exercise. However, there was again a tenuous positive significant relation between the MAP and absolute recovery SBP/percent recovery SBP at 3 minutes following the removal of exercise stimulus (r=0.25, p=0.01 Vs r=0.20, p=0.05).

In table 4, the RPP showed significant tenuous negative relation only with the percent recovery HR at 5 minutes into removal of exercise stimulus (r=-0.28, p=0.00) but not with other variables. However, there was a significant and also tenuous relation between the MAP and the absolute recovery HR, absolute recovery SBP and percent recovery HR; r=0.21, p=0.03; r=0.23, p=0.02 and r=0.26, p=0.01 respectively.

Predictors of recovery heart rate and blood pressure one minute after exercise

Table 5, presents the factors that predict recovery, one minutes after the removal of exercise stimulus.

For the absolute recovery HR1, the model was significant, F-ratio=5.18, p=0.01, and R=0.42, hence the model was 42% of the variance in absolute recovery HR1. For absolute recovery SBP, the model was significant, F-ratio=5.06, p=0.01 and R=0.42, hence the model was 42% of the variance in absolute recovery SBP. For the absolute recovery DBP the model was significant, F-ratio=2.94, p=0.02 and R=0.33, hence the model explained 33% of the variance in absolute recovery DBP.

For percent recovery HR1, the model was significant, F-ratio=11.00, p=0.00, and R=0.56, hence the model is 56% of the variance percent recovery HR. For the percent recovery SBP, the model was significant, F-ratio=3.63, p=0.01 and R=0.36. The model is 36% of the variance in percent recovery SBP. For the percent recovery DBP, the model was significant, F-ratio=2.56, p=0.04 and R=0.39. the model is 39% of the variance in percent recovery DBP.

There was a modest negative significant influence of RPP on the absolute/percent recovery HR (β = -0.45, p=0.00 Vs β =-0.62, p=0.00). Hence the highest significant negative predictor of recovery HR at 1-minute post exercise was the RPP. This means that higher resting RPP lead to a low percent/absolute recovery HR (slower drops in HR) at 1-miute after exercise. However, the RPP showed a tenuous negative significant influence on the absolute recovery SBP/DBP (β = -0.25; p=0.03 Vs β = -0.26; p=0.03), but not on the percent recovery blood pressure (p=0.05 Vs p=0.06; SBP/DBP). This indicates again that higher resting RPP was associated with lower recovery of absolute blood pressure (slow drop in blood pressure) but not the percent recovery blood pressure.

The PP show a significant tenuous positive influence on absolute recovery SBP/DBP, percent recovery HR and percent recovery DBP; β =0.22, p=0.03; b=0.29, p= 0.01; β =0.23, p=0.02 and B=0.28, p=0.01 respectively, but not on the absolute recovery HR and percent recovery SBP (p>0.05). This means that the higher resting PP was associated with faster recovery (faster drops) in Absolute recovery blood pressure and percent recovery HR/DBP at one-minute post exercise.

Also, the MAP showed a modest positive influence on the absolute recovery HR/SBP, percent recovery HR/SBP; β = 0.38, p=0.00; β =0.41, p= 0.00; β = 0.40, p=0.00 and β =0.39, p=0.00 respectively, but no influence on the recovery DBP (p>0.05). No significant influence was found by the BSA on recovery drop in blood pressure and HR ($p>0.05$). Hence the MAP was the highest significant positive predictor of recovery HR and SBP. This indicates that higher MAP was associated with faster drops in recovery HR/SBP.

Discussion

The derived cardiovascular parameter such as the MAP, RPP and PP are important measures used to determine the perfusion of blood to all the body tissue, oxygen uptake/energy requirement by the myocardium, and body's ability to adjust to increase work load/metabolism. The ease in computation of these indices makes them very attractive for use in decision making for patient management in resource deprived environment such as in countries with low-middle level of income. Determining these indices by calculation is also a reliable, simple, reproducible and cheap method similar to very expensive and other non-invasive and risky invasive method often employed to monitor and manage patient in high-tech clinical settings.

The average BSA, resting RPP, resting PP and resting MAP for this cohort of subjects was considered normal. Normal value of BSA for males and females are; 1.90 m^2 and 1.60 m^2 respectively. The BSA is importance because it is useful in drug dosage calculation [cytotoxic agent] and to determine derived cardiovascular indicator [31]. The RPP pressure is a major indicator of the energy demand of the heart, a normal value fall between 5000-10000 and values above this put and individual at risk of developing a heart disease [32, 33, 34]. The MAP is a major indicator of blood perfusion to the key organs like the kidney and heart, with normal values rages from 70-100mmHg.

The BSA of the physically inactive subjects and that of the active subjects were similar in the present study. Similarities in resting PP among the intergroup as seen in this study contradicts findings by Shahraki et al. with a report of significant higher PP in the athletic than in the non-athletic subjects [23]. However, the baseline MAP was significant more in the physically active than in the inactive subjects. These findings were consistent with that of Shahraki et al. [23]. However, the present study recruited age match male subject, but the report of Shahraki et al. [23] was on female subjects.

Also, the resting RPP of the physically inactive subjects was significantly more than that of the active subject, this clearly indicates that the physical inactive subjects were at higher risk of developing heart disease. Values greater than 10,000, puts a person a greater risk of coming down with a heart disease [32, 33, 34]. Normal base line values for RPP have also be reported to fall between 7000-9000 [21].

Reduce resting RPP as seen in the physically active subjects in the present study indicates increase in parasympathetic nervous activity and tone believed to be cardio-protective [35]. This mean that the physically active subjects are safer with enhanced parasympathetic mediated cardio-protection than the physically inactive group [21].

This study also assessed the relationship between the derived indices (BSA, RPP, PP and MAP) and the absolute/percent recovery HR and blood pressure at 1, 3 and 5-minutes after the removal of exercise stimulus.

There was a negative significant relationship between the resting RPP and absolute/percent recovery HR, this indicates a relationship in inverse direction between the resting RPP and the recovery HR one-minute after the removal of exercise stimulus but not the recovery blood pressure. Similar finding was seen between the resting RPP and the HR and blood pressure recovery three-minutes post removal of exercise stimulus. The resting RPP showed an inverse relationship again with the percent recovery HR at five minutes post exercise however, resting RPP was not significantly related to the absolute recovery HR/blood pressure.

There was a positive significant relation between the resting PP and absolute recovery SBP/percent recovery DBP one-minute post exercise, but not on the recovery HR or percent recovery SBP or absolute recovery DBP. This indicates that the higher the resting PP, the higher the higher the absolute recovery SBP/percent recovery DBP. However, there was no significant relation between the PP and the recovery HR/blood pressure at three-five minutes post exercise.

The resting MAP showed a significant positive relationship with the absolute/percent recovery SPB but not on the recovery HR or DBP at one-three minutes post exercise. This also indicates that the higher the MAP, the higher the recovery SBP. Interestingly, we found a significant positive relationship between the MAP and the recovery HR at five minutes post exercise.

A significant negative influence of the resting RPP on the absolute/percent recovery HR and absolute recovery SBP/DBP, means that a higher RPP reduces the chances of the subject's HR and blood pressure from recovering faster (lower change in recovery) one-minute after a bout of exercise. Higher values in the RPP put a person a at risk of sustaining a heart disease [32, 33, 34], and lower/slower recovery in HR one-minute after the cessation of exercise have been reported to put an individual at risk of dying within one year [13, 14]. A positive significance influence of the resting PP on the absolute recovery SBP/DBP, percent recovery HR/DBP, indicates that higher PP increases the absolute recovery SBP/DBP and percent recovery HR/DBP (higher change in recovery). Also, a positive significance influence of the resting MAP on the recovery HR and SBP, means that higher MAP increases the chances of the HR and SBP to recovery faster one-minute after the removal exercise stimulus. Elevated MAP leads to increase in shearing force on blood vessel wall, this favours the synthesis of NO with a net effect of relaxation [vasodilation] of the blood vessels perfusing the smooth muscle [2]. The faster [higher change in recovery] the rate of recovery of HR and blood one-minute post exercise removal signifies fitness. On the reverse side, it has been hypothesized by some researchers that a slower drop-in blood and HR one-minutes after a bout exercise, is an independent and powerful risk of predicting death in the space of one year and a useful marker during prognosis [13, 14].

4.5 Limitations and strengthen of the study

Interpreting the result of this study should done considering some limitations. First, the measurement of BSA, MAP, PP, and RPP, were calculated using measurement of blood pressure and HR and were not direct measures. Second, the inability to measure other derived indexes such as the CI, SV and CO could not allow us to determine a relationship and influence of physical activity status on these measures on the recovery blood pressure and HR. We recommend that further studies be carried out to determine the relationship and influence of these measures on the recovery drop in blood pressure and HR. Never the less, this study provided some insight on the relationship and influence of some derived cardiovascular parameter on the recovery blood pressure and HR post removal of exercise stimulus.

Conclusions

The present study found that the RPP at rest was significantly more in the physically inactive subject than in the active subject. Although no difference was found between the resting PP and BSA among the intergroup, there was a significantly higher difference in the MAP at rest in the physically active subjects than their sedentary counterpart. There was also an inverse relationship between the RPP and absolute/percent recovery HR at one-minute post exercise removal. Contrary wise, a significant positive relationship was seen between the resting PP and absolute recovery SBP/percent recovery DBP one-minute post exercise. The resting MAP also showed a significant relationship with the absolute/percent recovery SBP one-minute post exercise. The highest negative predictor of absolute/percent recovery HR and absolute recovery SBP/DBP was the RPP while, the highest positive predictor of recovery HR and SBP was the MAP.

Abbreviations

HR_{max}, maximum heart rate; SBP, Systolic Blood Pressure; Vs, versus; PP, pulse pressure; MAP, mean arterial pressure; RPP, rate pressure product; HR_{rest}, resting heart rate; CI, cardiac index; PA, physical Activity; HR, Heart Rate; IPAQ, international physical activity questionnaire; DBP, diastolic blood pressure; SV, Stroke Volume; CO, cardiac output.

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Declarations

There authors here in declear that there is no competing interest associated with this study.

Tables

Table 1: Comparison of derived cardiovascular indices and body surface area among Physically inactive and physically active subjects

Variable	Physically inactive (n=51)	Physically active (n=51)	t-value	F- value	p-value
BSA	1.83±0.16 $metre^2$	1.86±0.16	-0.92		0.36
Rest PP	40.87±7.30 mmHg	41.59±7.88 mmHg	-0.48		0.63
Peak PP	48.18±12.33mmHg	55.33±15.04 mmHg		6.96	0.01
Rec PP 1	42.59±8.53 mmHg	46.94±10.33 mmHg	-2.23		0.02
Rec PP 2	42.80±10.12mmHg	45.45±13.36 mmHg	-1.13		0.26
Rec PP3	40.73±7.69 mmHg	43.02±11.18 mmHg	-1.21		0.23
Rest MAP	83.93±9.59 mmHg	87.91±7.98 mmHg	-2.28		0.03
Peak MAP	90.73±12.99mmHg	97.21±11.33 mmHg		2.78	0.09
Rec MAP 1	85.47±12.77 mmHg	89.98±10.01 mmHg	-1.98		0.05
Rec MAP 2	81.21±11.87 mmHg	85.60±7.89 mmHg	-2.20		0.03
Rec MAP 3	80.52±9.23 mmHg	84.46±8.83 mmHg	-2.20		0.03
Rest RPP	8742.71±1496.31	7790.18±1131.59	3.63		0.00
Peak RPP	13983.78±2904.78	16558.35±2972.10		42.77	0.00
Rec RPP 1	11022.65±2306.70	11167.90±2313.85	-0.32		0.75
Rec RPP 2	10229.55±1948.09	10166.73±1816.80	0.17		0.86
Rec RPP 3	9679.02±1595.94	9380.43±1529.97	0.96		0.34

Rest PP, resting pulse pressure; peak PP, peak pulse pressure; rest MAP, resting mean arterial pressure; peak MAP, peak mean arterial pressure; rec PP1, 2 and 3, pulse pressure 1, 3 and 5 minutes after exercise; rec MAP1, 2, 3, mean arterial pressure 1, 3 and 5 minutes after exercise; rec RPP 1, 2, 3, rate pressure product 1, 3 and 5 minutes after exercise; NS, p>0.05 not significant; *, p<0.05 significant; peak PP, MAP and RPP as based on analysis of covariance test

Table 2: Relationship between Body Surface Area, Derived cardiovascular indices and Recovery Heart Rate /Blood Pressure 1-minute after removal of exercise stimulus

Variables	ARHR1		ARSBP1		ARDBP1		% RHR1		% SBP1		% DBP1	
	R	P-value	r	P-value	r	P-value	r	P-value	R	P-value	r	P-value
BSA	0.09	0.37	0.04	0.67	-0.12	0.22	0.17	0.09	-0.02	0.81	-0.09	0.33
RPP	**-0.23***	**0.02**	0.03	0.79	-0.10	0.32	**-0.34****	**0.00**	0.01	0.92	-0.05	0.62
PP	0.05	0.59	**0.22***	**0.03**	0.19	0.05	0.12	0.23	0.14	0.16	**0.20***	**0.04**
MAP	0.18	0.07	**0.33****	**0.00**	0.02	0.84	0.16	0.10	**0.28****	**0.00**	0.07	0.46

BSA, body surface area; RPP, rate pressure product; PP, pulse pressure; MAP, mean arterial pressure; ARHR1, absolute recovery heart rate at 1-minute; ARSBP1, absolute recovery systolic blood pressure at 1 minute; ARDBP1, absolute recovery systolic blood pressure at 1 minute; %RHR1, percent recovery heart rate at 1 minute; %RSBP1, percent recovery heart rate at 1 minute; %RDBP1, percent recovery heart rate at 1 minute; ** correlation significant at 0.01; * correlation significant at 0.05

Table 3: Relationship between Body Surface Area, Derived cardiovascular indices and Recovery Heart Rate/ Blood Pressure 3-minute after removal of exercise stimulus

Variables	ARHR3		ARSBP3		ARDBP3		% RHR3		% SBP3		% DBP3	
	R	P-value	r	P-value	r	P-value	r	P-value	R	P-value	r	P-value
BSA	0.04	0.73	0.02	0.84	-0.08	0.44	0.14	0.18	-0.06	0.57	-0.09	0.54
RPP	**-0.20***	**0.04**	-0.11	0.27	-0.07	0.47	**-0.33****	**0.00**	-0.13	0.18	-0.06	0.54
PP	0.05	0.64	0.15	0.14	0.17	0.08	0.01	0.94	0.05	0.60	0.17	0.09
MAP	0.13	0.19	**0.25***	**0.01**	0.06	0.55	0.139	0.16	**0.20***	**0.05**	0.06	0.55

BSA, body surface area; RPP, rate pressure product; PP, pulse pressure; MAP, mean arterial pressure; ARHR1, absolute recovery heart rate at 3-minute; ARSBP3, absolute recovery systolic blood pressure at 3 minute; ARDBP3, absolute recovery systolic blood pressure at 3 minute; %RHR3, percent recovery heart rate at 3 minute; %RSBP3, percent recovery heart rate at 3 minute; %RDBP3, percent recovery heart rate at 3 minute; ** correlation significant at 0.01; * correlation significant at 0.05

Table 4: Relationship between body surface area, derived cardiovascular indices and blood pressure/heart rate recovery Recover 5-minute after removal of exercise stimulus

Variables	ARHR5		ARSBP5		ARDBP5		% RHR5		% SBP5		% DBP5	
	R	P-value	r	P-value	r	P-value	r	P-value	R	P-value	r	P-value
BSA	0.06	0.55	0.03	0.77	-0.10	0.34	0.17	0.09	-0.03	0.77	-0.10	0.30
RPP	-0.16	0.10	-0.01	0.95	-0.01	0.89	**-0.28****	**0.00**	-0.08	0.43	-0.04	0.70
PP	-0.06	0.53	0.18	0.06	0.07	0.48	-0.01	0.90	0.07	0.46	0.08	0.43
MAP	**0.21***	**0.03**	**0.23***	**0.02**	0.20	0.84	**0.26****	**0.01**	0.12	0.24	-0.01	0.95

BSA, body surface area; RPP, rate pressure product; PP, pulse pressure; MAP, mean arterial pressure; ARHR5, absolute recovery heart rate at 5-minute; ARSBP5, absolute recovery systolic blood pressure at 5 minute; ARDBP5, absolute recovery systolic blood pressure at 5minute; %RHR5, percent recovery heart rate at 5 minute; %RSBP5, percent recovery heart rate at 5 minute; %RDBP1, percent recovery heart rate at 5 minute; ** correlation significant at 0.01; * correlation significant at 0.05

Table 5: Influence of derived indexes on heart rate /blood pressure recovery

Variables	ARHR		ARSBP1		ARDBP1		% RHR1		% SBP1		% DBP1	
	B	P-value	B	P-value	B	P-value	B	P-value	B	P-value	B	P-value
BSA	-0.01	0.92	-0.08	0.41	-0.20	0.05	0.04	0.62	-0.13	0.198	-0.18	0.08
RPP	**-0.45****	**0.00**	**-0.25***	**0.03**	-0.26	0.03	**-0.62****	**0.00**	-0.23	0.05	-0.22	0.06
PP	0.12	0.24	**0.22***	**0.03**	**0.29****	**0.01**	**0.23***	**0.02**	0.15	0.15	**0.28****	**0.01**
MAP	**0.38****	**0.00**	**0.41****	**0.00**	0.12	0.31	**0.40****	**0.00**	**0.39****	**0.00**	0.15	0.19

BSA, body surface area; RPP, rate pressure product; PP, pulse pressure; MAP, mean arterial pressure; ARHR1, absolute recovery heart rate at 1-minute; ARSBP1, absolute recovery systolic blood pressure at 1 minute; ARDBP1, absolute recovery systolic blood pressure at 1-minute; %RHR5, percent recovery heart rate at 1 minute; %RSBP1, percent recovery heart rate at 1 minute; %RDBP1, percent recovery heart rate at 1 minute; ** correlation significant at 0.01; * correlation significant at 0.05