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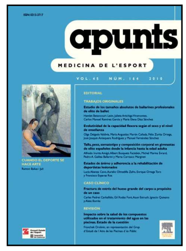

REVIEW

Blood pressure response to exercise testing

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Blood pressure;
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Abstract
Although blood pressure is usually measured during and in recovery from a stress test, there are no clearly established figures of an abnormal response. Different methods and population studies give different definitions. This conflicting data had provoked an inadequate appreciation of clinical significance, and the conduct to follow. This article revises work relevant to blood pressure response in stress tests, and based on evidence, proposes a series of values and conducts of diagnostic and prognostic significance.

PALABRAS CLAVE
Presión arterial;
Prueba de esfuerzo;
Reacción hipertensiva;
Reacción hipotensiva;
Hipertensión futura

Respuesta de la tensión arterial a la prueba de esfuerzo

Resumen
Aunque en la práctica se mide la presión arterial durante y en la recuperación de la prueba de esfuerzo, no hay cifras claramente establecidas de una respuesta anormal. Diferentes poblaciones y métodos estudiados explican las diversas definiciones. Estos datos conflictivos provocan una inadecuada apreciación de su significancia clínica y de la conducta que hay que seguir. Este artículo revisa trabajos relevantes de la respuesta de la presión arterial a la prueba de esfuerzo, y basándose en la evidencia, propone una serie de valores y conductas de significancia diagnóstica y pronóstica.

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Introduction

Exercise testing is a cardiovascular stimulation test which is performed on treadmill or bicycle, monitoring the electrocardiogram and blood pressure (BP). It has a relatively low cost and is normally used to estimate prognosis, to determine the functional capacity, to assess the probability and extent of coronary disease and to evaluate the effects of treatment or physical training.

There are relatively few studies which provide figures for normal pressure response during exercise for adults and adolescents. These studies take into account the age and sex, which is not normally taken into consideration when evaluating a pressure response during exercise.

The manual determination of the BP is still used routinely in practice. It can sometimes be difficult to define the values of resting blood pressure, especially diastolic blood pressure (DBP), either by auditory problems, to define or recognize the fifth Korotkoff sound, or an auscultatory gap. In practice, even with experience, it often can be even more difficult to define the figures for systolic blood pressure (SBP) and DBP during exercise testing, especially the latter. For example, sometimes the DBP during effort can not be defined in the fifth Korotkoff sound, because sound is heard almost to 0 mmHg, the fourth must be used to define DBP. The determination of the BP through automatic equipment, with the right technique, offer many advantages over the manual technique, having verified its utility and clinical validity.

As for what is considered to be an abnormal response of blood pressure during effort, even today, there is no clear agreed consensus. The definitions use different parameters and methods of study are also different. Usually absolute figures are taken, although, clearly, there may not have the same clinical significance in blood pressure at maximal effort of 230 mmHg in an adult of 25 years as in one of 65. Furthermore, possibly the clinical and prognostic significance is not sufficiently valued, leaving some people at possible risk without adequate monitoring or additional studies.

The abnormal BP responses can develop during the test, in recuperation, and even just before exercise testing, having significant clinical value. The hypertensive response (HR), hypotensive, as in an insufficient BP response form part of the abnormal responses during exercise testing. The BP response during the recuperation, frequently not adequately valued, can also contribute relevant clinical information. It is also important to take into account the safety pressure figures during exercise testing, both those of the contraindications as well as the test termination criteria.

The relevance of the BP study in effort lies in its diagnostic potential, not only for arterial hypertension, but also to reflect other pathologies that may alter hemodynamic, such as hypertrophic cardiomyopathy. It also has a potential prognosis on future hypertension, cardiovascular events, stroke and mortality.

This article summarizes recent evidence of studies on the abnormal response of blood pressure in exercise testing, outlining guideline figures for diagnosis and prognosis purposes, with the aim of improving the interpretation and implementation in daily practice.

Normal response

The normal response of blood pressure in progressive exercise testing is: SBP increases while the DBP is maintained or decreases slightly.

The normal response of SBP in progressive tests is approximately 7 to 10 mmHg by MET, about 25 watts, although there are no standard values[1-4].

The tension response at submaximal and maximal effort level, and during recovery is dependent on age, sex and physical condition, which should be taken into account when assessing a response in normal exercise testing (Figure 1 and Table 1)[5-7].

Age

For older patients, one would expect to observe higher values of SBP and DBP in submaximal and maximal effort, and also in recovery[6,8,9].

Sex

Generally men have a higher maximal value of SBP (SBPmax) and a quicker recovery than women[8,10].

Physical fitness

In trained subjects the response of SBP is less in submaximal effort than in non-trained subjects, reaching greater SBPmax with normal values of 225-240 mmHg at high level. By increasing physical fitness, SBPmax increases[4,8,11,12]. Thus, the maximal Delta SBP (i.e., the difference between SBPmax and the resting SBP) reaches greater values in athletes.

The maximal pulse rate (SBP-DBP) during exercise, is also higher in athletes than non-athletes, often exceeding 100 mmHg[13].

Athletes reach a lower DBPmax[4]. In healthy young people, sometimes the DBP cannot be determined because it can be heard to almost zero level.

Poor physical condition is associated with higher blood pressure responses at submaximal and maximal effort[14].

There is usually post-effort hypotension (values below the initial level) in both normotensive and in hypertensive patients which may last several hours[1].

Adult and adolescent hypertensive patients, or those with high body mass index, have higher BT responses during physical effort[7,15]. The SBP response was higher in obese adolescents, indicating a greater reactivity to physical exertion[16].

Auscultatory methods

The manual method is still recommended during exercise testing, although it must be remembered that the central BP or its equivalent, the brachial artery, is that which is validated for a proper diagnosis, and prognosis of cardiovascular morbidity and mortality[17].

In general, the automatic measurements of BP correlate well with the manual methods and have clinically acceptable absolute differences. Generally there is an underestimation with the DBP during increasing effort intensity; some

Table 1 Maximal blood pressure and percentiles by age and gender

	Men		Women	
Age-group (years)	Systolic (mmHg)	Diastolic (mmHg)	Systolic (mmHg)	Diastolic (mmHg)
20-29				
Means ± SD	182 ± 21	71 ± 12	156 ± 20	70 ± 12
Percentile 5°	146	50	124	49
Percentile 95°	218	89	188	89
30-39				
Means ± SD	184 ± 20	76 ± 12	160 ± 22	74 ± 11
Percentile 5°	150	58	24	52
Percentile 95°	218	94	196	90
40-49				
Means ± SD	188 ± 21	80 ± 12	167 ± 23	78 ± 11
Percentile 5°	154	60	130	59
Percentile 95°	224	98	208	96
50-59				
Means ± SD	193 ± 23	83 ± 12	177 ± 24	81 ± 12
Percentile 5°	157	62	138	60
Percentile 95°	233	101	215	99
60-69				
Means ± SD	197 ± 24	84 ± 12	186 ± 24	81 ± 13
Percentile 5°	159	66	148	60
Percentile 95°	239	105	228	100
70-79				
Means ± SD	196 ± 27	84 ± 13	185 ± 25	83 ± 10
Percentile 5°	151	60	144	63
Percentile 95°	243	105	222	100

SD = standard deviation
Adapted from Daida et al[6].

Table 2 Hypertensive response and risk or future hypertension

Year (source)	Population (number)	Follow-up (years)	Ergometer/Protocol	Definition HR (mmHg)
1994 (21)	Normotensive (3,741)	5	Bruce	SBPmax >210 men and 190 women
2001 (27)	Normotensive (190)	5.7 (5-8)	Bruce	SBPmax >200 y DBPmax >100
1999 (23)	Normotensive (150)	7.7 ± 2.9	Bruce	SBPmax >214
1998 (32)	Normotensive (5,386)	4 ± 5	Balke	Increase in delta SBP >60/6.3 METs, >70/8.1 METs, delta DBP >10
2000 (34)	High normal (239)	5.1	Cycle 12.5 w/min	Upper quartile (delta TAS = 33-59 at 50% of HRres)
2002 (33)	Normotensive (1,033)	4.7 (3.6-6.9)	Cycle 12.5 w/min	Percentile 90 (according % HRres)
1999 (31)	Normotensive (2,310)	8	Bruce	SBPrec and DBP max >percentile 95
2004 (34)	Normotensive (75)	1	Bruce	SBPmax ≥11 mmHg/MET

DBP: diastolic blood pressure; DBPmax: maximal value of DBP; HR: hypertensive response; HRres: reserve heart rate; SBP: systolic blood pressure; SBPmax: maximal value of SBP.

clinically validated (Schiller AG, BP-200 plus, Baar, Switzerland; Colin Medical Instruments, Colin 630, San Antonio, Texas)[18,19] and others, specific to exercise testing, have been recommended and validated with an intra-arterial catheter (SunTech Medical Inc., Tango+, Eynsham, UK)[20].

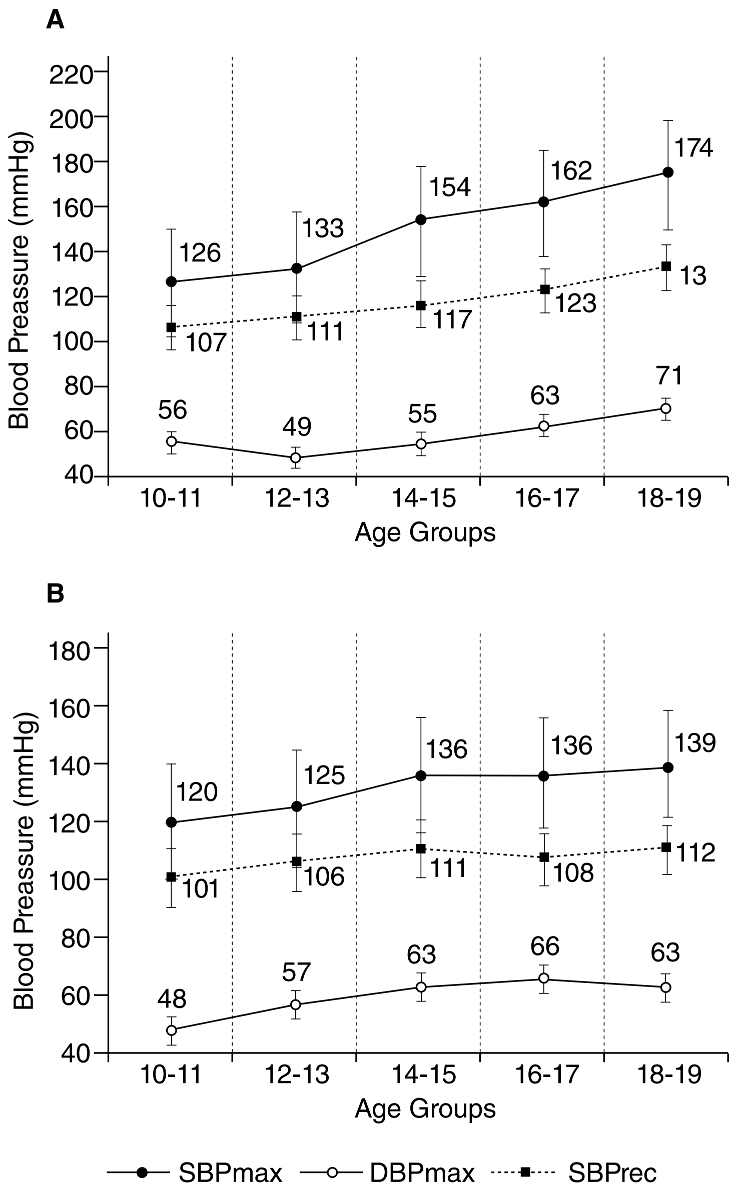

Figure 1 A) Blood pressure values in maximal exercise and recovery at 6 minutes by age (men). B) Blood pressure values in maximal exercise and recovery at 6 minutes by age (women).

Logically, and more so in exercise testing, due to environmental noise and patient motion, it is important to take into account possible common causes of error in the evaluation of BP such as an inappropriate manometer or inadequate cuff size, poor condition of ear tips, too long a tube, the rate of inflation and deflation of the cuff, the experience of the Tester, inadequate site or pressure of the stethoscope, background noise, tension in the hand and forearm or flexion of the elbow during the take.

Automatic exercise testing equipment improves some of these drawbacks, although correct pre-test adjustment is needed, as well as the correct location of the microphone and the right placement of the electrodes, as they need an electrocardiograph signal for measurement. A short training period is required, but this is reliable and clinically practical, as we can automate the times of taking blood pressure, including recovery, and there are graphics and measurements integrated into most of the stress-test software.

Abnormal response

During exercise testing

a) Hypertensive response

There is no definition of hypertensive response in normotensive asymptomatic standard patients, there are proposed pressure figures.

SBPmax effort is commonly referred to at effort level[3, 21-30], but there are also figures at different submaximal levels[31,32], some of which take into account sex, other take into account other percentiles, or associate it with a percentage of fixed or variable effort: reserve heart rate[33,34], mmHg/MET[35], mmHg/min[30,36], others take into account the resting SBP and its variation in mmHg (DeltaSBP)[32, 37], others include DBPmax defined solely by this criteria[25-27,30,38].

Although the relevance of the diagnosis and the prognosis of a HR is not fully clarified, some of these patients have an increased risk of future hypertension[1,21,25,27-29,31-35,38-42], left ventricular hypertrophy or abnormal mobility[24,26,43-45], stroke[23,26], cardiovascular incidents[23,30], increased mortality[46,47], and endothelial dysfunction[48].

Other mentioned findings related to HR are: hypercholesterolemia[49], increased angiotensin II[50], inflammatory markers such as leukocytes[51], carotid atherosclerosis[22], arterial stiffness and albuminuria[52]. Prevalence ranges from 3-4% or more, according to studies[41].

Future hypertension

Early detection of hypertension can prevent a critical damage to key organs. Several studies found that an exaggerated BP response to physical effort is a prognostic factor for hypertension, even in children[53]. In general the work shows a low sensitivity (25-40%) with high specificity (73-90%)[23,32,34].

Singh et al[31], in the Framingham Heart Study, refer to the 95 percentile of the SBP and DBP in the second stage of a Bruce, and do not consider a SBPmax as a predictor of future hypertension (RR = 1 in men and RR = 1.4 in women), but do, the DBPmax (RR = 4.2 in men, RR = 2.2 in female), and the SBPrec in men (RR = 1.9).

Matthews et al[32], with participation from the Cooper Institute, take into account the DeltaSBP relate it to the effort level in METs, and also consider the increase of DBP. The refers to a relative risk of 3.0 modified by several other factors.

Miyai et al[34] when considering individuals with habitually high blood pressure also take into account the DeltaSBP at an effort level of 50% the reserve heart rate, i.e. a submaximal level. They mention a relative risk of 2.3 of future hypertension. Another study[33] with normotensive subjects shows SBP max and DBPmax percentiles curves in relation to heart rate reserve. Beyond the 90 percentile indicates a relative risk of 3.8.

Manolio et al[21] established as a single cut-off point, a fixed SBPmax level. A prevalence of 18% was observed with an incidence of 4.9%. The odds ratio for predicting future hypertension was 1.7 ($p<0.001$), likewise including cardiovascular events.

Zanettini et al[35] studied 75 normotensive subjects with an ergometric Bruce test during one year, finding that individuals with a HR have a higher BMI, a thicker left ventricular posterior wall and a higher SBP in ambulatory measurement. They conclude that the detection of HR is better detected than the value of 210 mmHg, if the variation of the BP is corrected by the amount of work done. The cut-off was ≥11 mmHg/MET (Table 2).

Several studies illustrate that the DBP response in exercise has a similar or greater predictor force than SBP for future hypertension, with DBPmax values greater than 90/100 mmHg or an increase >10 mmHg[26,27,31,38].

Cardiovascular event

Laukkanen et al[30] studied 1731 middle-aged men, seemingly healthy, in cycloergometer, with 12.7 years of follow up. The greater SBPmax of 230 mmHg was associated with an adjusted RR of 2.47 for risk of myocardial infarction. Among those with a high resting BP, an excessive increase in the BP curve, greater than 9.4 mmHg per minute of exercise, had a RR of myocardial infarction of 4.31.

Kurl et al[36] studied 1026 healthy men, with a follow up of 10.4 years, on cycloergometer for 20 W/min, and noted that a hypertensive response during exercise and recovery were directly and independently associated with risk of a stroke (Table 3).

b) Hypotensive response

Although there is no consensual agreement on its definition, the two most common are *a)* a drop in SBP below standing rest levels, *b)* an initial SBP increase followed by a fall equal to or greater than 20 mmHg[54-56]. The first has a significant relative risk of 3.2 for cardiovascular events, while the predictive value of the second is lower. The prevalence varies between 5 and 8% and was higher in patients with coronary heart disease[41]. A hypotensive response may reflect a hypertrophic cardiomyopathy (HCM), the same as a flat response. In studies of patients with HCM, the hypotension patterns observed were: a sustained fall of the SBP as from the first minutes of exercise >20 mmHg or an initial increase, with subsequent decrease of 20 mmHg or greater. A flat response was defined as a change in the SBP during effort less than 20 mmHg, compared with the resting SBP[57,58].

c) Poor response

Active people have a lower resting SBP, during exercise, and also in DeltaSBP. The amplitude the SBPmax response in effort appears to be a mortality risk factor independent of resting BP12.

Table 3 Hypertensive response and risk of cardiac events

Year (source)	Population (number)	Follow-up (years)	Ergometer/Protocol	Definition HR (mmHg)
2006 (30)	Normotensive (1,731)	12.7	Cycle 25 w/2 min	SBPmax >230 >9.4 mmHg/min
2001 (36)	Normotensive (1,026)	10.4	Cycle 20 w/2 min	19.7 mmHg/min

Hedberg et al37 studied 382 elderly men and women (average age 75) and found that an increased response of DeltaSBP in exercise is associated with better long-term survival in older adults. The greater the increase (>55 mmHg) the lower the mortality rate for all causes (RR = 2.6, and of ≤30 mmHg, RR = 5.1). For every 10 mmHg increase in SBP, relative risk for all causes decreased by 13%, and for cardiovascular mortality by 26%, after taking several factors into account.

Gupta et al[46] studied 6145 men with an average age of 53 ± 12 years who did exercise testing limited by symptoms. An increase in SBP ≤44 mmHg was a significant predictor of mortality, independent of other factors such as age, ST segment, and exercise capacity, with a RR = 1.2. An increase ≥44 mmHg in exercise testing was associated with a 23% improvement in survival, over a median follow-up greater than 6 years, independent of several factors (age, history of hypertension or coronary artery disease, functional capacity or ST abnormalities).

Naughton et al[47] studied 641 men with a history of myocardial infarction, for 3 years. He concluded that a poor SBPmax ≤140 mmHg is associated with high mortality. The exercise did not reduce mortality.

Sadrzadeh et al[59] concluded a retrospective study of 1959 men during follow-up period of 5.4 ± 2.1 years, that the double reserve product (maximal double product minus resting) seems to have more mortality prediction power than METs, maximal heart rate, maximal SBP, or recovery heart rate. A double product reserve less than 10,000 was a predictor of mortality (OR = 4.1).

During recovery

Huang et al[60] retrospectively studied 3054 patients referred for exercise testing, with 10 years follow up. A paradoxical increase in SBP after exercise (SBP to 3 minutes recovery ≥1 minute of recovery) is an important and significant predictor of cardiovascular mortality with an adjusted odds ratio of 1.80.

Nakashima et al[39] studied 138 men and 76 women with a mean age of 19 years at commencement of the study, for an average of 12 years. They did exercise testing for five minutes on a cycloergometer and recorded the BP immediately after exercise, and also at 50% of exercise intensity. The SBP and DBP immediately after exercise in men was shown to be a strong predictor of future hypertension, more so than the resting BP. In contrast, in women, the resting SBP was shown to be the best predictor.

Yosefy et al[61] studied 86 apparently healthy patients who came for a routine check, with an average age of 60 ± 4.1 (46-75) years, with Bruce test, measuring the SBP and DBP at 5 minutes of recovery. After 5 years of follow-up, those who had a HR, defined as >160/90 mmHg (small DeltaSBP of 46.9 ± 3.1 mmHg) developed a worse cardiovascular profile, and other adversities (abnormal cholesterol levels, hypertension and cardiovascular disease and stroke combined) with a RR of 1.32.

Tsumura et al[62] studied 6557 men, from 35 to 63 years of age, with a follow-up period of 63,696 person-years. Exercise testing was performed on a step (Master test) and found that the SBP and DBP at 4 minutes after exercise was associated with an increased risk of hypertension in normotensive and also in individuals with normal high blood pressure. The RR for the SBP and DBP after exercise was 1.55 per 10 mmHg. This was independent of resting blood pressure.

Laukkanen et al[63] studied 2336 individuals on cycloergometer with average age of 52.9 ± 5.1, with a follow up of 13.1 years. The average SBPmax was 202 mmHg, and at two minutes was 183 mmHg. The SBP >195 mmHg at 2 minutes of recovery was associated with a risk of myocardial infarction of 1.7. The adjusted RR was 1.45 for cardiovascular mortality and 1.68 for myocardial infarction.

Singh et al[31] studied 1026 men and 1284 women with an average age of 42 ± 10 years in the Framingham Offspring Study, normotensive, with 8 years follow up. They found that a recovery SBP at 3 minutes was predictive of hypertension in men, with an adjusted RR of 1.92 (average recovery SBP at 3 minutes of 142 ± 19 mmHg) (Table 4).

Safety of exercise testing

The risk during exercise testing is generally low and depends on the clinical characteristics of the patient.

The overall risk in a mixed population is approximately 6 events (myocardial infarction, ventricular fibrillation, other major arrhythmias, or death) in 10,000 tests[3].

Overall complications, major and minor, in apparently healthy people and athletes, is lower, estimated at approximately 1/10.000. Morbidity varies between 1-5 according to the studies and mortality of 0-0.4[64].

With regard to the BP, and without having defined evidence, with the aim of avoiding serious complications, it's best to follow the current recommendations of contraindication, and of finalization of exercise testing. One of the main reference guides is the that of the Committee of the Stress Tests of the American College of

Table 4 Recovery and cardiac events

Year (source)	Population (number)	Follow-up (years)	Ergometer/Protocol	Definition HR (mmHg)
2008 (60)	3,054	10	Bruce	SBPrec 3' >1'
2006 (61)	Normotensive (86)	5	Bruce	BP >160/90 at 5'
2004 (63)	Normotensive (2,336)	13.1	Cycle	SBPrec >195 at 2'
1999 (31)	Normotensive (2,310)	8	Bruce	SBP 142 ± 19 at 3'

Cardiology and American Heart Association, which also follows the American College of Sports Medicine[3,25].

Contraindications for exercise testing

The American Guide does not refer to any absolute contraindication to a resting BP whilst the Spanish Guide mentions a resting BP of 240/130 mmHg[42].

In the guide, a relative contraindication is shown as severe arterial hypertension, considering the same higher levels of 200/110 mmHg in rest[25].

Indications for terminating the exercise testing

An absolute indication to stop testing, is considered to be a drop in the SBP of >10 mmHg from the initial value of the BP, despite an increase in workload, when accompanied by other evidence of ischemia.

Within the relative factors, is considered the before mentioned, but when there is no evidence of ischemia. Also considered a relative indication the hypertensive response, which in the absence of definitive evidence, is defined as a higher SBP of 250 mmHg and/or greater than a SBP 115 mmHg (Table 5).

Discussion

Undoubtedly, the recorded BP during and after exercise can give us valuable information clinically. The problem is, that there are few benchmarks, and also sometimes in practice the existing variations of age, sex, fitness and body mass index are not taken into account.

Often taken into account in practise, is the SBPmax, only as a reference standard, meaning that it can sometimes be difficult to determine the DBPmax.

Frequently pulse pressure is not taken into account, nor the DeltaSBP nor not completing the taking of BP in the recovery, which we have seen can provide clinically relevant data.

Undoubtedly, conducting exercise testing is the only way to determine an abnormal response to exercise.

The guide of the American College of Cardiology and American Heart Association, both mention the excessive elevation of SBP as DBP during exercise as an indicator of future risk of hypertension in asymptomatic normotensives, and a SBPmax greater than 214 mmHg or higher SBP or DBP in the third minute of recovery[25] and also refer to as a hypertensive reaction the figure of 250/115 mmHg, relative indication to stop an exercise test.

The reference of an exaggerated response in blood pressure sometimes indicates only the SBPmax, as the figures of Manolio et al[21] of 210/190 mmHg in men and women respectively, or also report the SBPmax and DBPmax, like those of Sharabi et al[27] the 200/100 mmHg respectively. Similarly, other studies such as that of Framingham, find only the DBPmax or recovery SBP predictors of hypertension[31]. Here reference tables are provided of the expected values of 95 percentile, gender and age-specific, although they are values derived from the second stage of the Bruce test. Thus, we have SBPmax values for men of 20, up to 70 years of age, ranging from 190 to 218 mmHg and of women of similar age range from 165 to 203 mmHg. Therefore, they do not put fixed maximal numbers for all patients, but instead take into account the age and sex.

On the other hand, there are other authors who, as a future risk of hypertension propose figures that take into account other parameters relating to the behaviour of the BP during effort. For example, the work of Matthews et al[32], at the Cooper Institute, which takes into account variations in SBP during exercise, the DeltaSBP and relates it to the level of effort according to the METs. Likewise, Miyai et al[34] uses percentiles curves in relation to effort, in this case, the reserve heart rate. Also Zanettini et al[35] establishes that it is better than a set number, in this case 210 mmHg, to relate the variation of the BP with the work performed in METs. Laukkanen et al[30] and Kurl et al[36] also report increased risk figures in this case of a cardiovascular event, but related to the increase of SBP in the time, that is, per minute.

A hypotensive response has a high degree of prognostic significance and may reflect a decrease in cardiac output or severe heart disease[54-56], although this can indicate other conditions such as cardiomyopathy, arrhythmias, or irregularities such as a vasovagal reaction or that produced by medication. The hypotension which may occur immediately after exercise, due to peripheral vasodilatation and fall in venous return, should not be considered a hypotensive response[41].

An inadequate response of SBP during effort, the DeltaSBP, should also be measured and considered as a significant predictor of mortality. The lower the SBP response to stress, the greater the risk. Figures deemed to be insufficient, as a response of SBP during effort, range from 20 to 45 mmHg[37,46,47].

Table 5 Safety instructions in exercise testing

	Absolute	Relative
Contraindications	• Clinical criteria • 240/130 mmHg at rest	• >200/100 mmHg at rest
Suspension	• Drop in SBP > 10 mmHg from baseline BP despite an increase in workload, and other evidence of ischemia	• Drop in SBP > 10 mmHg from baseline BP despite an increase in workload, and without other evidence of ischemia • SBP >250/115 mmHg

SBP: systolic blood pressure.

With regard to BP during recovery, studies show a relationship between an abnormal response and future hypertension and cardiovascular mortality. There are studies including a significant population and likewise monitored for several years[60-63], although differing in the methods of determination as in the definition, with figures suggested from the first until the fifth minute. A recent study by Huang et al[60] relates the importance of a paradoxical increase in SBPrec at 3 minutes longer than the first, as being a significant predictor of mortality. Most other studies have proposed specific numbers, one of the most frequently mentioned being the Framingham study (142 mmHg at 3 minutes) as a predictor of future hypertension in men.

This highlights the need for future studies that incorporate consideration of age and sex. It may be appropriate to consider establishing percentiles and relating them to the level of effort in which the pressure figures are established.

Conclusions

There have been many studies undertaken regarding the diagnosis and prognosis of an abnormal response of the BP during effort, both during the recovery period, and even prior to commencing[65].

However, no standard values have been determined which are accepted globally, perhaps in part, due the different methods used in these studies.

In general, the abnormal response of the BP during effort is related to an increased risk of future hypertension or cardiovascular events and mortality.

In the event of an abnormal response in an asymptomatic patient, a study of primary hypertension should be considered. Likewise more frequent clinical control of resting BP, an echocardiogram, a 24 hour Holter as a more dynamic test, and even a repetition of the exercise test, as this same abnormal response may not be repeated[66]. In case of an insufficient or hypotensive response, a possible ischemic cardiopathy and ventricular function should be studied.

Certainly more studies are needed and a consensus regarding the abnormal response of the BP during effort. Meanwhile, based on the studies mentioned previously but without defining set blood pressure, and likewise taking into account age, sex and physical condition of the patient, and above all the clinical context, we can consider an abnormal response of BP during effort in the following cases:

- SBPmax values greater than 210/190 mmHg in men and women respectively, may represent an exaggerated response in adults.
- SBPmax values greater than 230 mmHg may be considered higher risk. SBP values of >250 mmHg and DBP >115 mmHg define a clearly hypertensive result.
- DBP values greater than 100-105 mmHg or increase >10 mmHg at any time during the test.
- A hypotensive response, i.e. a drop in SBP below the initial values, a decrease equal to or greater than 20 mmHg or an increase of less than 20 mmHg during the entire effort.
- A low SBPmax, less than 140 mmHg.
- A reduced DeltaSBP to below 45 mmHg.
- Double reserve product <10.000.
- Sudden, steep increases greater than 10-12 mmHg/MET can be considered abnormal. It might be appropriate to routinely measure DeltaSBP between METs reached during the test.
- Paradoxical increase of SBP during recovery, i.e. a SBP at 3 minutes more than that of the first minute
- Slow SBP recovery, i.e. maintaining high values during the first minutes of recovery (see Table 4). It might be advisable to routinely measure the BP recovery 2-3 times during the first minutes of recovery.

In summary, significant increases in the SBP and DBP during effort, low or falling levels of SBP during effort, low amplitude of the DeltaSBP and slow recovery of the SBP are considered abnormal responses of the BP and have a significant prognostic value of future hypertension and/or cardiovascular events and indicate the need for additional studies.

Conflict of interests

The authors declare they have no conflicts of interest.

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