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Impact of Adapted Physical Activity on Blood Pressure and Hypertension Control in the Militaries of Kinshasa Garrison, Democratic Republic of Congo: A Randomized Controlled Trial

Impact de l'Activité Physique Adaptée sur la Pression Artérielle et le Contrôle de l'Hypertension Artérielle des Militaires de la Garnison de Kinshasa, République Démocratique du Congo : un Essai Randomisé Contrôlé

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Résumé
Contexte & objectifs. Handicap majeur à la mise en condition opérationnelle des troupes, l'hypertension nécessite des approches innovantes pour sa prévention et contrôle. L'objectif de la présente étude était d'évaluer l'impact de l'activité physique adaptée (APA) sur la pression artérielle (PA) et le contrôle de l'hypertension chez les militaires sédentaires de la garnison de Kinshasa. *Méthodes*. Essai contrôlé randomisé, ouvert et parallèle, réalisé au Camp Lt-Colonel Kokolo (CVEC) de juin 2016 à octobre 2017 chez des militaires sédentaires (57,6 % hypertendus) affectés pendant 8 semaines au groupe APA (n=119) ou au groupe contrôle (n=110). La procédure de randomisation a utilisé des blocs permutés de quatre participants consécutifs. *Résultats*. A la dernière visite disponible chez 226 participants (119 contre 107), la différence de PA ajustée aux valeurs initiales entre les groupes actif et témoin selon le principe d'intention de traiter était de 5,1 (IC à 95 % 1,2 -10,8) vs 3,0 (0,1-6,9) mmHg plus faible dans le groupe actif. L'effet de l'APA était également significatif dans les catégories de participants prédéfinies en fonction de l'âge, du grade militaire et de l'hypertension. Parmi 129 hypertendus traités analysés (68 contre 61), le taux de contrôle de la TA est resté inchangé dans le groupe témoin (43,8 à 44,3 %) mais a augmenté (43,5 % à 85,3 %) dans le groupe actif, soit une différence entre les groupes de 40,7 (32,2; 49,2) %. La probabilité d'obtenir un contrôle de l'hypertension était plus élevée (HR: 3,38 [IC à 95 %: 1,48; 4,84] dans le groupe actif. L'analyse PP de 122 soldats (80 contre 42) avec des données à toutes les visites programmées a donné des résultats confirmatifs pour la réduction de la PA et pour le contrôle de l'hypertension par l'APA. Les modifications de la PA étaient positivement corrélées aux réductions concomitantes de la fréquence cardiaque.

Summary
Context and objective. Major handicap for operational conditioning of troops, hypertension requires innovative approaches for its prevention and management. The present study aimed to evaluate the impact of adapted physical activity (APA) on BP level of sedentary soldiers from Kinshasa garrison and the rate of hypertension control in those with high BP. *Methods*. Open, parallel randomized controlled trial carried out at Camp Lt-Colonel Kokolo (CVEC) from June 2016 to October 2017) in sedentary soldiers (57.6 %, hypertensives) allocated for 8 weeks to APA (n=119) or control (n=110). The randomization procedure used permuted blocks of four consecutive participants. The outcomes were baseline-adjusted between-group difference in BP level (all participants), in rate of BP control among hypertensives. *Results*. At the last available visit in 226 participants (119 vs 107), the baseline-adjusted BP difference between active and control group by intention-to-treat was 5.1 (95 % CI 1.2 -10.8)/3.0 (0.1-6.9) mmHg lower in the active group. The effect of APA was also significant across pre-specified categories of participants based on age, officers' rank, and hypertension status. Among 129 analyzed drug treated hypertensives (68 vs 61), the rate of BP control remained unchanged in the control group (43.8 to 44.3%) but increased (43.5% to 85.3 %) in the active group yielding a baseline-adjusted between group difference of 40.7 (32.2; 49.2) %. The probability to achieve hypertension control was greater (HR: 3.38 [95% CI: 1.48-4.84] in the active group. PP analysis of 122 soldiers (80 vs 42) with data at all scheduled visits yielded confirmatory results for BP reduction and for hypertension control by APA. The changes in BP were positively correlated with concomitant reductions in heart rate. *Conclusion*. Exercise training induced a significant BP reduction in sedentary militaries and improved the control rate among those with drug treated hypertension.

Keywords: Physical activity, Blood pressure, Hypertension control, Military, DR Congo

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Conclusion. L'entraînement physique a induit une réduction significative de la PA chez les militaires sédentaires et a amélioré le taux de contrôle chez les personnes souffrant d'hypertension traitée par des médicaments.

Mots-clés : Activité physique, pression artérielle, contrôle hypertension, militaires, RD Congo
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Introduction

Due to its association with serious clinical conditions such as stroke, ischemic heart disease and end-stage chronic kidney disease (1), hypertension is the main cause of morbidity and mortality in the world (2). Moreover, its prevalence is increasing (3-4) despite clear recommendations formulated by expert societies for its prevention and management (5).

In the military profession, the cardiovascular system is the most stressed of all the systems of the human organism. Blood pressure (BP) is the main target and hypertension the main result with its complications and its harmful consequences, both physical and socio-professional, in combatants (6).

Thus, the professional environment of the military represents an excellent locus for the study of cardiovascular health through, in particular, intervention programs aimed at preventing chronic diseases (7).

The American Heart Association advocates adapted physical activity (APA) as key element in the definition of cardiovascular health (8). Physical inactivity is an acknowledged risk factor for cardiovascular morbidity and mortality, including by hypertension (1). Thus, any cardiovascular disease prevention program should assess the physical activity of subjects.

No study has been conducted on APA among the militaries from the Armed Forces of the Democratic Republic of the Congo which are in quasi-permanent campaign. The present intervention study was therefore undertaken to assess whether an APA training program would impact BP level of sedentary militaries from the Kinshasa garrison and improve hypertension control among those with high BP.

Methods

Trial design, setting and population

Open, parallel randomized controlled trial was carried out at the Cardiovascular Exploration Center (CVEC) of Camp Lt-Colonel Kokolo at Kinshasa between June 2016 and October 2017.

Eligible population consisted of active status sedentary militaries not involved in any kind of leisure time or competition sport, resident in Kinshasa and aged 20 to 75 years. Enrolment by informed consent was recorded in writing with freedom to withdraw without constraint.

Selection criteria

Criteria for non-inclusion were serious illnesses such as chronic renal, hepatic, respiratory or cardiac insufficiency, or end-stage neoplastic condition and pregnancy for women. A steering Committee at CVEC) randomly assigned the 229 eligible participants either to the intervention (n=119) or the control (n=110) arm using permuted blocks of four consecutive soldiers.

Intervention and outcomes

Participants in the intervention arm (active group) underwent 8-week adapted physical activity (APA) training that consisted of a 50-minute walking session on flat ground three mornings a week on odd (Monday, Wednesday, Friday) or even days (Tuesday, Thursday, Saturday) of the week. The control group was invited to a leisure seated game of checkers or cards at the edge of the same field, during a similar period and at the same weekly frequency. At the beginning of each session, BP and HR were measured in all participants. Three consecutive BP measurements one minute apart were obtained in sitting position using an Omron model M3 electronic BP monitor with suitable cuff secured on the left arm, the military having observed a 5-minute rest before the first measurement. HR was recorded at the same time as BP. The mean of these three measurements was used in the analysis. Demographic (gender, age) and professional information (military rank) and history of hypertension were obtained at the screening visit. Eligible soldiers with confirmed hypertension (SBP ≥140 mmHg and/or DBP ≥ 90 mmHg or use of antihypertensive treatment) (9) were given amlodipine 5-10 mg and/or hydrochlorothiazide 12.5-25 mg for at least 4 weeks prior to randomization. This drug treatment was maintained throughout the follow up.

The primary outcome was the baseline-adjusted between-group difference in BP level for all participants and baseline-adjusted between group difference in the rate of BP control among the hypertensive participants. The secondary study outcome was time to BP control in these under drug treatment hypertensive individuals. Hypertension control was SBP< 140 mmHg and DBP< 90 mmHg. In order to demonstrate a 5 mm Hg difference in systolic BP (s.d.: 12 mm Hg) with a two-sided P of 0.01 and 90 % power, at least 180 randomized subjects, 90 per group, were required.

Statistical analyses

Data were compiled into an Excel 2010 database of weekly BP and HR monitoring. The results were presented as means (± standard deviation), medians (interquartile range) and proportions (%) as appropriate. Two analyses of the data were performed. The main analysis applied the intention-to-treat (ITT) principle including all randomized participants with at least one follow-up visit available (Primary analysis). As sensitivity analysis the per-protocol (PP) principle only included subjects with data at each scheduled visit. For ITT analysis we considered the baseline-adjusted between group differences in BP and HR at the last available visit for each randomized participant. For the PP analysis the baseline-adjusted between group differences at scheduled endline data are considered. Student's t-test, Mann-Whitney U-test, and Pearson's chi-square or Fischer's exact test were performed, respectively, to compare means, medians, and proportions in the two study groups. The effects of physical activity on continuous variables were evaluated using a mixed model analysis of variance with baseline BP or HR as fixed effects and the weekly day sequence as a random effect. For the Kaplan-Meier survival function estimating the probability of reaching the target BP in hypertensive participants, the comparison of the two groups used the log-rank test. Cox regression was used to compare the probability of achieving hypertension control. The statistical significance threshold was $p < 0.05$. Statistics were performed using IBM SPSS for Windows software version 24.

Results

Participant characteristics

Figure 1 illustrates the flow of participants in the present study where, of the 229 randomized soldiers, 122 (53.3 %) rigorously complied with the protocol; 107 (46.7 %) withdrew from the study, including 3 hypertensives (1.2 %) who did not show-up after randomization. The reasons why these soldiers prematurely left the study are mentioned.

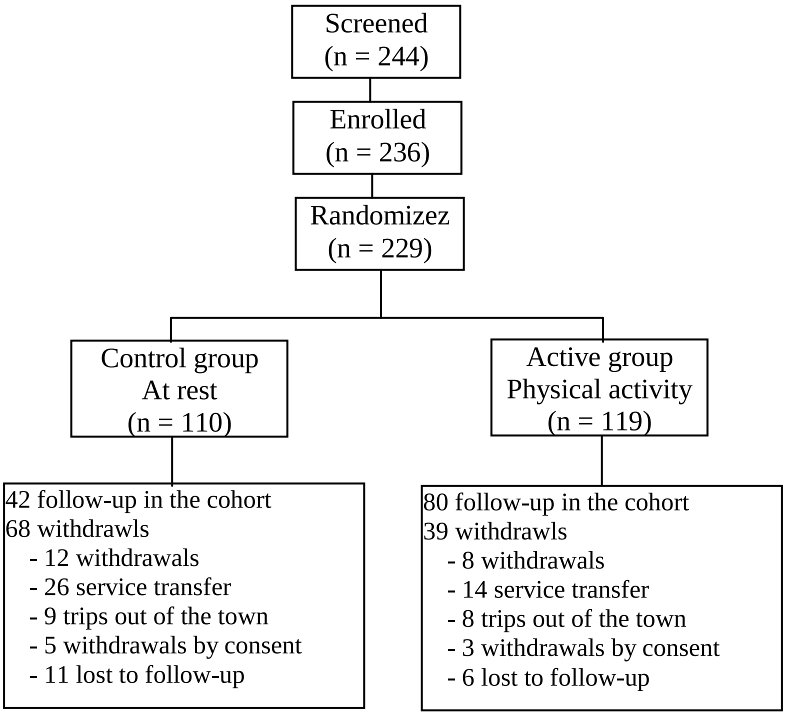


Figure 1. Participant flowchart

Table 1 compares the baseline characteristics of the control group and the active group for all randomized soldiers and for those with data at all scheduled visits (Cohort). For all the randomized soldiers, a significant difference between the two groups was observed for the mean age and heart rate. For the cohort, no difference between the two groups was significant. Supplementary Table S1 indicates soldiers who withdrew from the study had general characteristics similar to all randomized participants with regards to age, military rank and proportion of hypertensive participants.

Table 1. Baseline clinical characteristics of participants at randomization by type of analysis

Variable	ITT principle all randomized participants			PP¨ principle cohort seen at all scheduled visits		
	Control group n=110	Active group n=119	P	Control group n=42	Active group n=80	p
-Age (years)			0.052			0.558
< 50	33 (30.0)	49 (41.2)		15 (35.7)	29 (36.3)	
≥ 50	77 (70.0)	70 (58.8)		27(64.3)	51 (63.8)	
Officer rank			**0.085**			0.284
Juniors	66 (60.0)	57 (47.9)		23 (54.8)	38 (47.5)	
Seniors	44 (40.0)	62 (52.1)		19 (45.2)	52 (52.5)	
Hypertension			0.541			0.401
No	46 (41.8)	50 (42.0)		14 (33.3)	30 (37.5)	
Yes	64 (58.2)	68 (58.0)		28 (66.7)	50 (62.5)	
Age mean (years)	54.4 ± 8.3	51.9 ± 9.4	**0.038**	52.6 ± 8.1	52.4 ± 9.7	0.884
SBP (mmHg)	133.9 ±18.5	132.9±18.0	0.683	132.9±24.9	132.6±20.2	0.933

Variable	ITT principle all randomized participants			PP¨ principle cohort seen at all scheduled visits		
	Control group n=110	Active group n=119	P	Control group n=42	Active group n=80	p
DBP (mmHg)	83.9±11.3	82.3±10.6	0.276	83.9±15.9	82.2±11.5	0.490
HR (batt/min)	73.4±11.0	79.6±11.1	**0.001**	74.6±14.1	78.5±11.2	0.100
Follow-up time (Weeks)	6 (4-8)	8 (6-8)	**0.001**	8 (7-8)	8 (7-8)	1.000

ITT= intention-to-treat principle and PP = per protocol analysis principle. SBP= Systolic blood pressure; DBP= diastolic blood pressure; HR= heart rate

The duration of follow-up (median [IQR]) for all randomized participants was longer ($p < 0.001$) in the active group (8 [6-8] weeks) than in the control group (6 [4-8] weeks). It was similar in the two studies groups for the cohort.

Blood pressure and heart rate during follow-up

Figure 2 depicts SBP, DBP and HR (mean ± SE) during follow-up in the active and control groups for all randomized participants (Left) and for the cohort participants (Right). After randomization, SBP, DBP and HR significantly decreased in both groups for all randomized soldiers as well as for those in the cohort; the decrease being greater in the active group

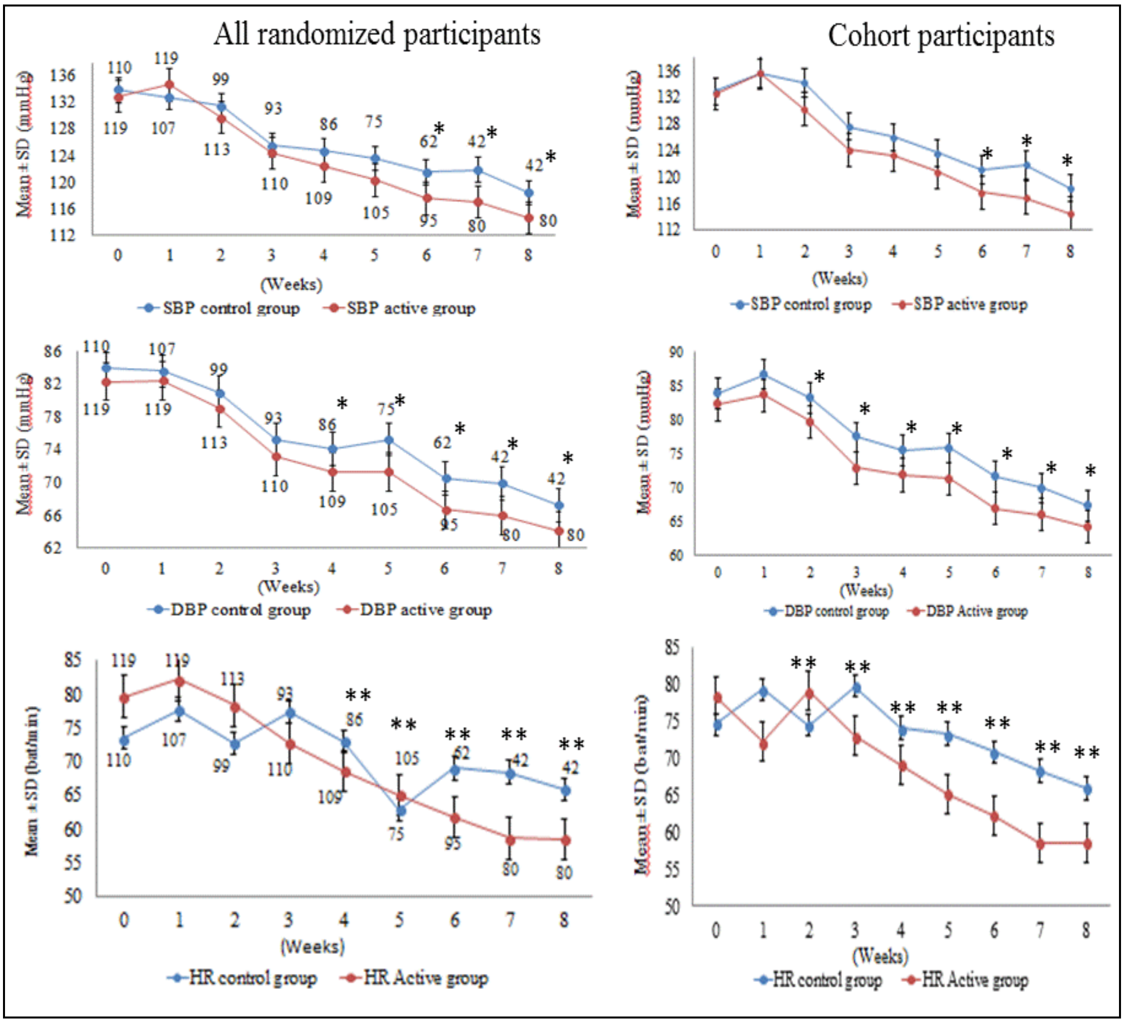


Figure 2. SBP, DBP and HR during follow-up for the active group (red) and the control group (blue). The left panel concerns all the randomized subjects. The number of participants at each follow-up week is shown. The right panel concerns the cohort of participants with data at each week of follow-up. The bars represent the mean ± standard error. *= p<0.05; **= p<0.01 for between group comparison

Changes in blood pressure and heart rate

Table 2 summarizes the changes in BP and HR and the between group differences according to ITT principle in 226 participants seen at least once after randomization (Control group 107; Active group 119). At the last available visit, the decrease in DBP was the only significant in participants assigned to control group whilst in the active group, SBP, DBP and HR were significantly reduced. The between group differences in the reduction of SBP, DBP and HR were significant and amounted respectively to -5.1(-10.8; -1.2) mmHg, -3.0(-6.9; -0.1) mmHg and -2.5(-8.2; -0.2) beats/min. When the mean of all available measurements was considered instead of the last available visit values, the baseline-adjusted between group difference in HR variations was the only significant. Per-protocol analysis of 122 participants (Control group 42; Active group 80) with data at all scheduled visits during follow up was confirmatory of the ITT analysis.

Table 2. Changes in BP and HR and between group differences by ITT analysis in 226 participants seen at least once after randomization

	ITT analysis			ITT analysis		
	SBP, mmHg	DBP, mmHg	HR, b/min	SBP, mmHg	DBP, mmHg	HR, b/min
Baseline value	133.9±18.5	83.9±11.3	73.4±11.0	133.9±18.5	83.9±11.3	73.4±11.0
Last available visit value	122.2±11.6	71.1±9.6	69.8±10.7	128.4±12.2	78.4±7.8	69.5±6.4
Within group difference	-11.7±3.3	-12.8±1.5	-3.6±1.7	-5.5±11.8	-5.9±7.7	-3.9±9.9
p-value	0.088	**0.046**	0.294	0.012	<0.001	0.063
Baseline value	132.9±18.0	82.4±7.6	79.6±11.1	132.9±18.0	82.4±7.6	79.6±11.1
Last available visit value	116.5±9.6	66.5±7.6	60.6±10.6	126.4±8.6	75.6±5.4	69.1±8.1
Within group difference	-16.8±8.7	-15.8±3.0	-6.1±2.8	-6.5±12.3	-6.8±7.9	-10.5±9.7
p-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Value (95% CI)	-5.1 (-10.8; -1.2)	-3.0 (-6.9; -0.1)	-2.5 (-8.2; -0.2)	-1.0 (-1.5; +0.5)	-0.9 (-1.1; +0.7)	-6.6 (-6.8; -6.4)
p-value	**0.015**	**0.042**	**0.041**	0.966	0.134	**0.001**

Values are expressed as mean ± standard deviation

Figure 3. illustrates the changes in BP and HR at the last available visit for 226 originally randomized soldiers (Left) and for the 122 soldiers with data at all weeks of follow-up (Right)

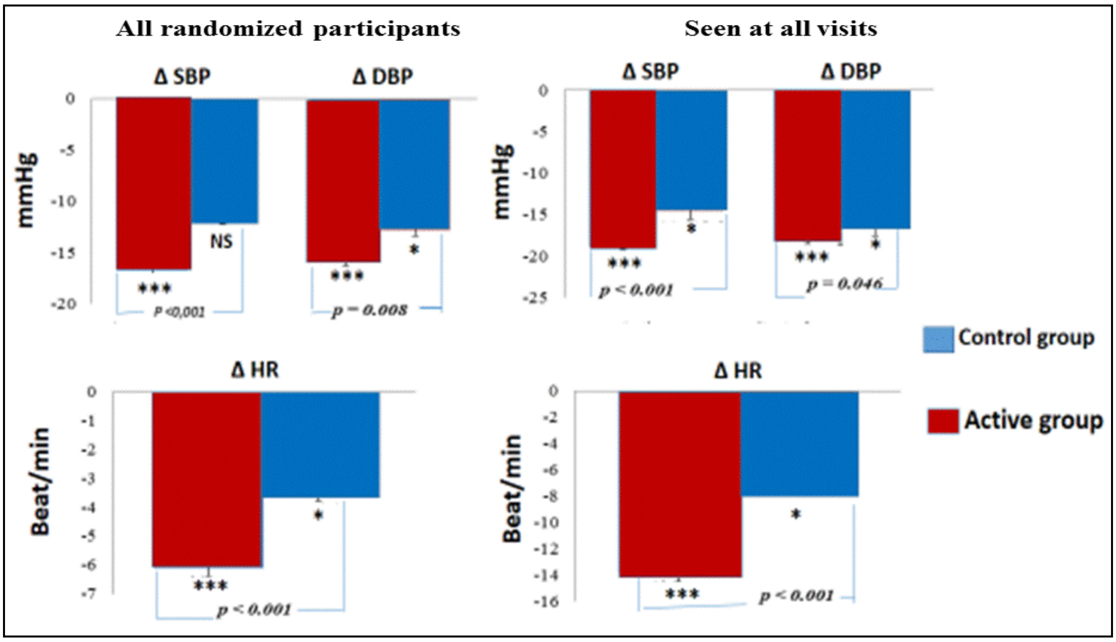
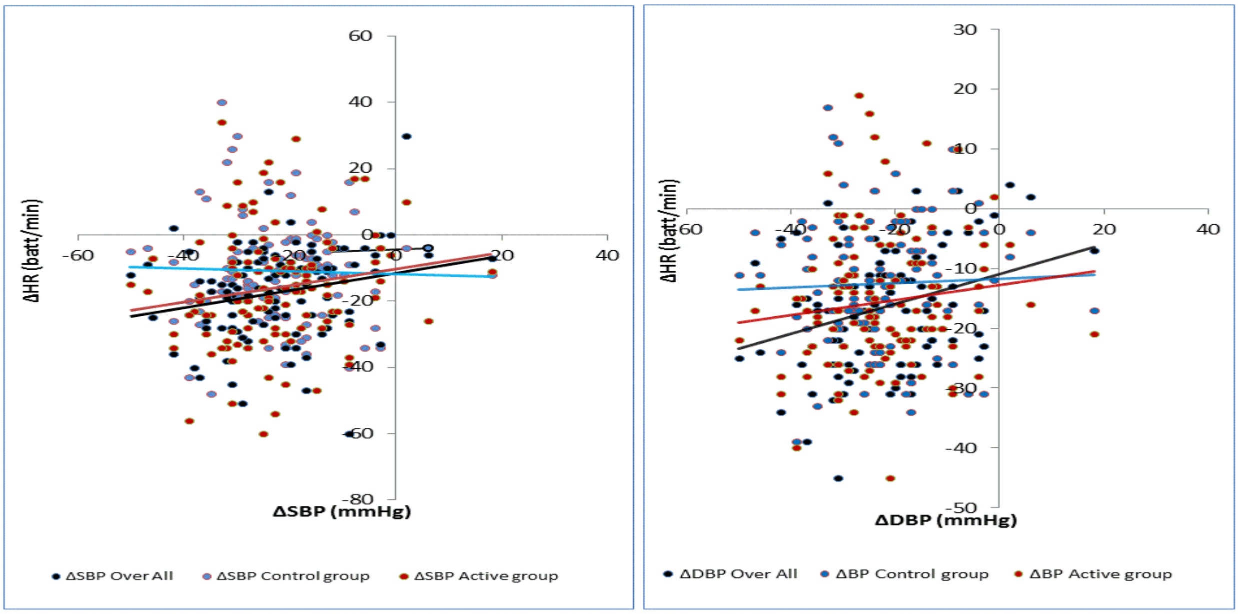


Figure 3. Differences (mean ± standard deviation) in SBP, DBP and HR between the values at the last available visit and baseline average in the active group (Red) and the control group (Blue) for all randomized participants (Left) and between endline visit and baseline for those with data at all scheduled visits (Right). The indicated p values refer to between groups' comparisons. NS= not significant; *=p<0.05; *** = p<0.001 for within group comparison

Determinants of blood pressure changes

Figure 4 illustrates positive correlations between changes in BP and concomitant variations in HR observed at the last available follow-up visit in all of the randomized soldiers and in the active or the control group considered separately. The correlation suggests that the decrease in BP was all the more important as that of HR was great.



	r (SBP)	p-value (SBP)	r (DBP)	p-value (DBP)
All the militaries	0.466	<0.001	0.474	<0.001
Control group	0.455	<0.001	0.458	<0.001
Active group	0.493	<0.001	0.580	<0.001

Figure 4. Significant positive correlation between the fall in SBP (left) and DBP (right) and that of HR, for all the randomized subjects (Black), and for active (Red) and control (Blue) group considered separately

Table 3 compares the reduction in BP and HR observed at the last available visit in various pre-specified categories among 226 randomized participants (107 control group; 119 active group) seen at least once during follow up (ITT analysis). The between group difference was significant in participants <50 years, in senior officers and in hypertensive participants for SBP and DBP; it was also significant for HR in the < 50 years, the junior and senior officers, and in non-hypertensive individuals. Endline observations among 122 participants (42 control group; 80 active group) with data at all scheduled visits (PP analysis) showed similar trends.

Table 3. Difference in blood pressure and HR changes in various categories of participants

Catégorie	Variable	ITT principle			p
		Control group (n=107)	Active group (n=119)	Between group difference (95%CI)	
Age (years)					
< 50	ΔSBP. mmHg	-8.3±16.7	-17.7±14.4	-9.4 (-13.1; -7.9)	**0.008**
	ΔDBP. mmHg	-10.8±11.4	-17.4±11.9	-6.6 (-10.5; -2.1)	**0.015**
	ΔHR. beat/min	-18.7±13.3	-24.8±11.3	-6.1 (-10.2; -2.5)	**0.033**
≥ 50	ΔSBP. mmHg	-12.0±14.5	-15.5±19.0	-3.5 (-6.9; 1.2)	0.221
	ΔDBP. mmHg	-13.2±11.1	-14.8±10.8	-1.6 (-3.4; 0.3)	0.404
	ΔHR. beat/min	-21.2±13.1	-22.9±17.3	-1.7 (-5.1; 0.6)	0.112
Officer rank					
Juniors	ΔSBP. mmHg	-10.6±17.2	-12.1±14.5	-1.5 (-3.3; 0.2)	0.602
	ΔDBP. mmHg	-12.4±12.0	-13.3±11.1	-0.9 (-1.8; 0.1)	0.666
	ΔHR. beat/min	-16.4±15.4	-22.3±12.3	-5.9 (-10.5; -3.4)	**0.021**
Seniors	ΔSBP. mmHg	-8.9±16.3	-21.7±15.5	-12.8 (-14.2;-9.8)	**<0.001**
	ΔDBP. mmHg	-11.3±11.3	-19.0±9.7	-7.7 (-11.2; -5.8)	**<0.001**
	ΔHR. beat/min	-21.4±14.5	-25.7±14.1	-4.3 (-7.7; -1.9)	**0.036**
Hypertension					
No	ΔSBP. mmHg	-2.8±13.5	-4.5±14.1	-1.7 (-3.3; 0.5)	0.547
	ΔDBP. mmHg	-6.6±12.3	-7.8±11.4	-1.2 (-1.9; 0.1)	0.935
	ΔHR. beat/min	-6.3±12.4	-9.3±13.2	-3.0 (-5.2; -1.3)	**0.027**
Yes	ΔSBP. mmHg	-10.9±16.5	-19.2±18.8	-8.3 (-11.7; -3.3)	**0.005**
	ΔDBP. mmHg	-11.7±11.0	-17.3±10.5	-5.6 (-9.4; -3.6)	**0.003**
	ΔHR. beat/min	-20.9±16.6	-24.6±13.0	-3.7 (-6.3; 1.5)	0.158

Catégorie	Variable	PP analysis			p
		Control group (n=40)	Active group (n=82)	Between group difference (95%CI)	
Age (years)					
< 50	ΔSBP. mmHg	-10.1±22.9	-21.3±12.9	-11.2 (-13.1; -6.2)	**0.044**
	ΔDBP. mmHg	-12.2±15.1	-20.3±10.0	-8.1 (-11.8; -5.4)	**0.038**
	ΔHR. beat/min	-21.6±13.9	-22.8±8.6	-1.2 (-4.3; 0.3)	0.170
≥ 50	ΔSBP. mmHg	-16.2±20.6	-17.1±16.1	-0.9 (-1.8; 0.1)	0.845
	ΔDBP. mmHg	-16.8±10.6	-19.1±10.0	-2.3 (-4.9; 1.2)	0.364
	ΔHR. beat/min	-18.9±16.9	-29.8±10.0	-10.9 (-13.2; -3.7)	**0.003**
Officer rank					
Juniors	ΔSBP. mmHg	-12.3±19.2	-17.4±19.6	-5.1 (-7.2; 2.1)	0.328
	ΔDBP. mmHg	-15.6±11.8	-19.7±11.8	-4.1 (-6.3; 1.9)	0.192
	ΔHR. beat/min	-18.6±16.4	-27.5±10.6	-8.9 (-11.2; -5.4)	**0.024**
Seniors	ΔSBP. mmHg	-11.2±17.8	-23.2±16.0	-12.0 (-13.9; -8.7)	**0.011**
	ΔDBP. mmHg	-12.9±12.3	-20.4±8.7	-7.5 (-11.8; -3.4)	**0.009**
	ΔHR. beat/min	-21.2±12.7	-30.0±12.8	-8.8 (-11.7; -6.8)	**0.015**

Catégorie	Variable	PP analysis			p
		Control group (n=40)	Active group (n=82)	Between group difference (95%CI)	
Hypertension					
No	ΔSBP. mmHg	-2.8±19.5	-3.3±14.1	-0.5 (-3.1; 0.1)	0.921
	ΔDBP. mmHg	-6.9±9.3	-8.3±13.5	-1.4 (-2.3; 0.5)	0.708
	ΔHR. beat/min	-10.1±12.1	-15.7±14.3	-5.6 (-11.1; -3.8)	**0.044**
Yes	ΔSBP. mmHg	-15.5±18.9	-20.9±20.0	-5.4 (-8.7; 3.9)	0.248
	ΔDBP. mmHg	-15.8±11.9	-18.8±11.2	-3.0 (-7.1; 1.2)	0.274
	ΔHR. beat/min	-21.7±15.7	-30.1±9.8	-8.4 (-11.8; -5.8)	**0.013**

ΔSBP, ΔDBP and ΔHR indicate the variation of SBP, DBP and HR within the group compared to the value at randomization. The between group differences (95% CI) are shown

In multiple linear regression analysis (Table 4), the variation in HR and the active group emerged as the only independent determinants of the changes in SBP and DBP as well per ITT as per PP analysis. Physical activity was associated, respectively, with 7.8/5.0 mmHg (p<0.001) lower BP by ITT analysis and 9.0/4.84mmHg (p=0.006) lower BP by PP analysis.

Table 4. Independent determinants of the change in SBP and DBP

Variables	By ITT analysis				By PP analysis			
	β	SE	95% CI	p	β	SE	95% CI	p
SBP								
(Intercept)	2.117	4.640	-12.0; 16.2	0.768	3.786	6.361	-18.9; 26.6	0.743
Activity	-7.841	1.254	-11.7; -4.02	**<0.001**	-9.052	1.789	-15.5; -2.6	**0.006**
Hypertension	-1.415	9.745	-5.2; 2.4	0.464	-2.704	0.467	-8.8; 3.5	0.384
Officer rank	-1.630	-0.044	-5.5; 2.3	0.409	-2.506	0.012	-8.6; 3.6	0.419
Age	0.067	0.073	-0.15; 0.28	0.541	0.113	0.093	-0.22; 0.44	0.502
ΔHR	0.570	0.213	0.44; 0.70	**<0.001**	0.658	0.061	0.44; 0.88	**<0.001**
	R^2 = 0.533 ; ** Random p<0.001				R^2 = 0.520 ; **Random p<0.001			
DBP								
(Intercept)	-5.820	3.980	-15.6; 3.9	0.240	-7.801	4.564	-21.9; 6.3	0.276
Activity	-5.003	1.076	-7.6; -2.4	**<0.001**	-4.838	1.284	-8.8; -0.9	**0.017**
Hypertension	0.468	1.072	-2.2; 3.1	0.725	1.388	1.228	-2.4; 5.2	0.471
Officer rank	-0.685	1.093	-3.4; 1.9	0.614	0.266	1.227	-3.5; 4.1	0.890
Age	0.066	0.060	-0.08; 0.21	0.381	0.022	0.066	0-.18; 0.23	0.835
ΔHR	0.404	0.038	0.31; 0.50	**<0.001**	0.394		0.26; 0.53	**<0.001**
	R^2 = 0.530 ; **Random p<0.001				R^2 = 0.475 ; ** Random p<0.001			

**Random p was obtained using a Hausman specification test to verify a hypothesis

Hypertension control

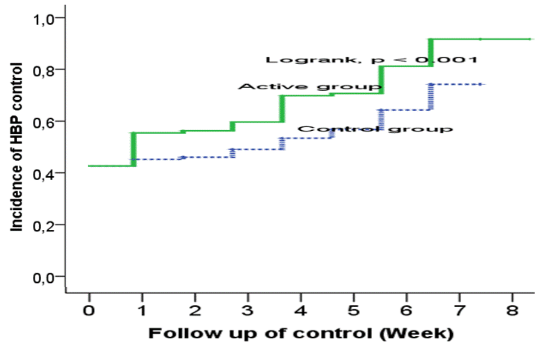
Of the 132 randomized hypertensive participants, 129 (Control group 61; Active group 68) were seen at least once during follow-up and were thus available for ITT analysis (Table 5). At randomization, the proportion of controlled hypertensive participants in the active group (43.5 %) and in the control group (43.8%) was similar (p=0.221). At the last available visit, hypertension control was achieved by 58 (85.3%) patients in the active group and 27 (44.2%) patients in the control group. The baseline-adjusted between group difference in hypertension control amounted to 40.7 (95 % CI 32.2; 49.2) % higher in the active group. Table 5 also describes the rate of BP control in 77 hypertensive participants (Control group 28; Active group 49) with data at all scheduled follow up visits (PP analysis). The baseline-adjusted between group difference in the rates of hypertension control at endline visit amounted to 45.9(95% CI: 34.8; 57.0) %.

The between group differences in the rate of hypertension control were not significant in pre-specified subgroups based on age category or officers' rank neither by ITT nor by PP analysis (data not shown).

Table 5. Blood pressure control in hypertensive participants during follow up by ITT and PP analysis

ITT Analysis		BP not controlled	BP controlled	PP Analysis		BP not controlled	BP controlled
Control group n=61	At baseline	27 (56.2)	34 (43.8)	Control group n=28	At baseline	22 (78.6)	6 (21.4)
	At last available visit	34 (55.7)	27 (44.3)		At last available visit	20 (71.4)	8 (28.6)
	Within group difference %(95% CI)	0.5 (0.1; 2.3)			Within group difference %(95% CI)	7.2 (0.2;16.8)	
	p-value	0.970			p-value	0.538	
Active group n=68	At baseline	38 (55.9)	30 (44.1)	Active group n=49	At baseline	33 (67.3)	17 (34.7)
	All last available visit	10 (14.7)	58 (85.3)		All last available visit	6 (12.2)	43 (87.8)
	Within group difference %(95% CI)	41.2 (28.8;53.6)			Within group difference %(95% CI)	53.1(39.1; 67.1)	
	p-value	<0.001			p-value	<0.001	
	Between group difference % (95 % CI)	40.7 (32.2;49.2)			Between group difference % (95 % CI)	45.9 (34.8;57.0)	

The median time interval from randomization to BP control was 4 (IQR: 1-5) weeks for the active group and 6 (IQR: 3–7) weeks for the control group (Figure 5; log- rank p<0.001).



No at risk									
active group	68	67	66	63	62	62	54	49	49
Control group	61	58	55	54	51	43	42	28	28
No of events									
active group	58	57	56	53	53	53	47	43	43
Control group	27	27	25	24	21	14	13	8	8

Figure 5. Kaplan-Meier survival function estimates for the probability of achieving BP control among all hypertensive militaries randomized (ITT principle) to the control group (n=61) or the active group (n=68). The control was a BP<140 mmHg systolic and <90 mmHg diastolic. P-value is for log-rank test significance

The results of the hypertensive participants in the cohort (PP analysis) were confirmatory of the observations in all the randomized soldiers (Table 5; Supplementary Figure S1).

In the Cox regression with adjustments applied for BP at randomization the probability of achieving hypertension control was 3.4 times greater for participants in the active than in the control group (HR 3.38; 95% CI: 1.48-4.84; p< 0.001).

Discussion

The present study evaluated the impact of an APA program on BP level among sedentary militaries of the Kinshasa garrison and on hypertension control among those with high blood pressure. According to ITT analysis the salient results reveal as primary outcome a reduction in BP significantly greater in the active group compared to the control group. Analyses of various participant categories based on age, military's rank or presence of hypertension showed greater reduction of BP among participants assigned to the active intervention group. In hypertensive militaries allocated to exercise training a higher rate of and a greater probability with a shorter time to reaching BP control was also observed. The PP analysis of the participants who rigorously followed the study protocol was confirmatory of these results.

The 8 week APA program resulted in baseline-adjusted BP difference of 5.1/3.0 mmHg lower among sedentary soldiers assigned to the active intervention arm compared to the control group. The between group baseline-adjusted difference amounted to 4.3/2.0 mmHg when only those who strictly complied with the study protocol were considered. Observation of lower BP level in the presence or in response to regular physical activity is consistent with data from the literature. Indeed, large epidemiological surveys have often reported an inverse relationship between BP and usual physical activity level assessed by questionnaire or interview, or with measurements of the physical fitness of the individuals (10-11). In addition, exercise and physical fitness were inversely related to the later development of hypertension (11). Within a population, the difference in BP between the most and the least active subjects does not exceed 5 mmHg after adjustment for confounding factors such as age, anthropometric data and lifestyle (12). If maintained for a sufficient period, such a difference in BP could favorably affect cardiovascular mortality. At the population level, a 2 mmHg lower SBP leads to 10 % reduction in stroke mortality and 7 % reduction in ischemic heart disease mortality (13); a 2 mmHg lower DBP is associated with 15 % and 6 % reduction in the risk of coronary heart disease and stroke, respectively (14). However, such observational relationships do not make it possible to affirm a causality between BP and the level of physical activity of populations. There are many confounding factors that cannot be taken into account, such as self-selection, genes for which adjustment is hardly possible (12). Hence, the importance of longitudinal interventions as in the present study.

A meta-analysis of 72 randomized controlled trials with 105 study groups reported in response to endurance training program a lowering of resting BP of 3.0/2.4 mmHg after weighing for trained participants and adjustment for control groups (15). Endurance training also reduced daytime BP (-3.3/-3.5 mmHg) obtained by 24-hour ambulatory measurement (12) and even BP measured during a stress test (- 7 mmHg for SBP for a drop in HR of 6 beats/min) (16).

The between group difference in SBP in our study is of the same order as that in the observational surveys; it somewhat exceeds the weighed values reported above in the meta-analyses, probably because our series consisted exclusively of black participants. The effect of race on exercise-induced lowering of BP was examined by Whelton SP *et al.* (17) in whites, blacks and Asians. The authors found, compared to whites, that Asians had a greater reduction in DBP and blacks a more marked reduction in SBP.

The small size of the female participants in our series did not allow a separate analysis of the impact of physical training on BP according to gender. However, gender in the literature does not seem to exert significant influence (18-19). On the other hand, the reduction of BP in response to physical training in our soldiers showed certain variations depending on the slowing of HR, age and the presence of hypertension. In addition, the reduction in BP was found to be greater in senior than in junior officers.

Concomitantly with the decrease in BP, APA caused a drop in HR of 2.5 beats/min greater in all militaries randomized to the active group and of 7.7 beats/min for the soldiers in the cohort. A positive correlation was observed between the changes in these two hemodynamic parameters. When adjusting the reduction in BP for various variables in a multiple linear regression analysis, the reduction in HR and physical activity were the only independent determinants accounting for 53.3 % of the variation in SBP and 53 % in DBP of randomized participants. These observations indicate the lowering of BP was all the greater the more physical training had concomitantly slowed heart rate. They suggest that common mechanisms might underpin the two hemodynamic modifications.

In militaries aged < 50 years, the APA induced a significant reduction in BP of 9.4/6.6 mmHg while the drop in BP only reached 3.5/1.6 mmHg in older participants. The literature does not seem unanimous as to the influence of age on the effect of physical training on BP. Ishikawa K *et al.* (19) who subjected individuals of different ages to an 8-week APA found, like us, a more marked reduction in BP in subjects < 50 years compared to those aged 50 to 69 years. Garrido ALM *et al.* (20) speculated that younger individuals might have done aerobic exercise more intensely than the older ones, even though the duration of the activity was the same. Another explanation could be that younger individuals do have less obesity indices (adipose tissue, BMI, etc.) which are inversely related to the reduction in BP (21). On the other hand, in their meta-analysis, Fagard R and Cornelissen V did not find any significant relationship between the net changes induced by training on BP at rest and the age of the subjects at baseline (15). BP decreased by 3.8 (1.8;5.8)/2.0 (0.6;3.5) mmHg in the 31 groups of participants with mean age < 40 years, 2.3 (1.1;3.6)/2.1(1.2;2.9) mmHg for those aged 40-59, and 5.4 (2.8;8.1)/3.3(1. 8;4.8) mmHg in those aged 60y and over.

Our results indicate a more pronounced BP reduction in response to APA among hypertensive [8.3(3.3;11.7)/5.6 (3.6;9 .4)] mmHg than normotensive militaries [1.7 (-0.5;3.3)/1.2 (-0.1;1.9;)] mmHg. These results corroborate previous studies in which normotensives and hypertensives had been, as in our work, subjected to the same physical training program (22) and where the lowering of BP was more pronounced in hypertensives. On average, the weighed reduction in BP was 13(11;15)/8(6;10) mmHg in hypertensives and 3 (0.5;10)/2 (–1;5) mmHg in normotensive individuals (15). The observation was similar in the already mentioned meta-analysis of 72 randomized trials where exercise training induced BP reduction was more marked in 30 groups of hypertensive [6.9(4.6 ;9.1)/4.9(3.3;6.5) mmHg] than in 72 groups of normotensive subjects [2.0 (0.9;3.0)/1.6 (1.0;2.3) mmHg]. Our results therefore support the recommendations of regular physical exercise as a non-pharmacological measure for the prevention and control of hypertension and cardiovascular diseases (5,9,23-24).

The rate of hypertension control that was similar in both groups at randomization, remained unchanged at the last visit available during follow-up in the control group whilst it had practically doubled in the militaries allocated to the physical activity program by ITT analysis. The between group baseline-adjusted difference in hypertension control amounted to 40.7 %. The probability of hypertension control was 3.4 times greater with a shorter delay to reach the target BP (< 140/90 mmHg) in the active group participants. This benefit of physical training on hypertension control was not affected by age category or military rank. At the endline visit, the PP analysis in the militaries who complied with the protocol was confirmatory of these observations.

With both ITT and PP analysis the effect of physical endurance training was found to be more pronounced in senior as compared to junior officers. The reason for this variance is unclear. It cannot be attributed to a greater proportion of hypertensives among the highest-ranking militaries because, as reported elsewhere, this proportion was similar in the present series (25). The ages of senior officers and junior officers were not compared. However, the active group was younger with slightly more of senior officers. Finally, although the intensity of exercise was the same for all randomized soldiers, the total duration may not have been identical for all subgroups and it is not known to what extent this could have impacted the lowering of BP (26).

The mechanisms accounting for the exercise training induced lowering of BP have not been investigated in the present study. It is known, however, that following a physical training program a resetting of the sympathetic system activity occurs as well as an improvement in the sensitivity of the baroreceptors with ensuing reduction in peripheral vascular resistance and, hence, a lowering in BP (20,27). The demonstration of a lower level of norepinephrine in trained subjects testifies such decrease in sympathetic tone (15,28). Endothelial changes induced by physical activity could also explain the increased sensitivity of baroreceptors (29) and may also be linked to the renin angiotensin aldosterone system. Félix et al showed that three months of exercise in spontaneously hypertensive rats was able to normalize high levels of angiotensinogen messenger RNA (30). The resulting decrease in ANG II and decrease in plasma renin may contribute to BP control (31). Urata et al found that individuals who had a reduction in plasma renin after physical training had a greater reduction in BP (32). M'Buyamba-Kabangu *et al.* reported that the degree of training was associated with physical fitness and conversely with plasma renin activity (33). Thus, the main mechanisms responsible for the lowering of BP after exercise are the reduction in cardiac output and peripheral vascular resistance. The importance of each of these mechanisms could vary according to the individual profile of the hypertensive (20,34).

This study has the merit of demonstrating the feasibility and effectiveness of an approach to the prevention and control of cardiovascular diseases among sedentary soldiers through a physical training program. The open design of the trial likely resulted in more frequent dropouts among participants consigned to rest. But overall the characteristics of the withdrawals and those who persevered in the study were similar, making it possible to extend the results to all of the randomized population for the proposed type, frequency and intensity of physical activity. Physical activity induced reduction in BP was less marked in normotensives but more pronounced in hypertensive participants, thus appropriate (with a probably favorable benefit/cost ratio) for secondary prevention. The response to medical treatment was not a main issue of the present trial where drugs used were the same in both study arms. BP reduction especially in the control arm might largely result from this antihypertensive treatment the adherence to which was unfortunately not assessed. Nevertheless, the significant changes from baseline BP and rate of hypertension control greater in the active arm do highlight the impact of exercise training. The proportion of women was marginal and could not allow a separate data analysis according to gender. In addition, cardiovascular risk factors that are common in the Congolese armed forces, such as overweight/obesity, lipid disorders and diabetes mellitus, were not taken into account in this evaluation of the effect of physical activity. Admittedly, the diet would not have an additive effect on physical activity (35), but we cannot affirm whether the participants had absolutely abstained from non-pharmacological measures such as sodium restriction and reduction of alcohol consumption.

Nonetheless, by showing a significant BP decrease in sedentary soldiers, our results support the recommendation that endurance physical activity constitutes a cornerstone for the prevention and control of arterial hypertension.

Conflict of interest

The authors declare no conflict of interest.

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Author's contributions

GKK and JRMK designed the protocol, interpreted the results and wrote the article. GKK, MMG, BBFE, KNN, MMR, BBN conducted the survey. ANN built the database and analyzed it; JMKN, BLM and JRMK coordinated the study. All authors reviewed the manuscript and approved the final version.

References

1. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, *et al.* Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension* 2003; **42** (4):1206-1252.
2. Lawes CM, Vander Hoorn S, Law MR, Elliott P, MacMahon S, Rodgers A. Blood pressure and the global burden of disease 2000. Part II : estimates of attributable burden. *J Hypertens* 2006; **24** (3):423-430.
3. Valderrama AL, Gillespie C, King SC, George MG, Hong Y, Gregg E. Vital Signs: Awareness and Treatment of Uncontrolled Hypertension Among Adults - United States, 2003-2010. *Morbidity and Mortality Weekly Report* 2012; **61** (35): 703-709.
4. McAlister FA, Wilkins K, Joffres M, Leenen FHH, Fodor G, Gee M, *et al.* Changes in the rates of awareness, treatment and control of hypertension in Canada over the past two decades. *Canadian Medical Association Journal* 2011; **183**: 1007-1013.
5. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Himmelfarb CD, *et al.* ACC/AHA/AAPA/ABC/ACPM/AGS/APHA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol* 2018; **71**: e127-e248. doi: 10.1016/j.jacc.2017.11.006
6. Goetzel RZ. Health, Absence, Disability, and Presenteeism Cost Estimates of Certain Physical and Mental Health Conditions Affecting U.S. Employers. *J Occup Environ Med* 2004; **46**:398-412.
7. Shamian J, El-Jardali F. Healthy workplaces for health workers in Canada: Knowledge transfer and uptake in policy and practice. *Healthcar Papers* 2007; **7**: 6-25.
8. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, *et al.* Defining and setting national goals for cardiovascular health promotion and disease reduction: The American Heart Association's strategic Impact Goal through 2020 and beyond. *Circulation* 2010; **121** (4): 586-613.
9. Williams B, Mancia G, Spiering W, Rosée EG, Azize M, Burnier M, Clement DL. ESH/ESC Guidelines for the Management of Arterial Hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Cardiology (ESC), and of the European Society of Hypertension (ESH). *Eur Heart J* 2018; **39** (33):3021-3104.
10. Fagard RH. Physical exercise and coronary artery disease. *Acta Cardiol* 2002; **57**:91-100.
11. Fagard RH, Cornelissen V. Physical activity, exercise, fitness and blood pressure. In: Battagay EJ, Lip GYH, Bakris GL, editors. Hypertension, principles and practice. Boca Raton: Taylor and Francis Books; 2005. pp. 195-206.
12. Fagard RH and Cornelissen V. Effect of exercise on blood pressure control in hypertensive patients. *Eur J Cardiovasc Prev Rehabil* 2007; **14**:12-17.
13. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R, Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* 2002; **360**: 1903-1913.
14. Cook NR, Cohen J, Hebert PR, Taylor JO, Hennekens CH. Implications of small reductions in diastolic blood pressure for primary prevention. *Arch Intern Med* 1995; **155** (7):701-709.
15. Cornelissen VA, Fagard RH. Effects of endurance training on blood pressure, blood pressure regulating mechanisms and cardiovascular risk factors. *Hypertension* 2005; **46**: 667-675.
16. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. Exercise and hypertension: American College of Sports Medicine, Position Stand. *Med Sci Sports Exerc* 2004; **36**: 533-552.
17. Whelton SP, Chin A, Xin X, He j. Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials. *Ann Intern Med* 2002; **136**: 493-503.
18. Fagard RH. Physical activity in the prevention and treatment of hypertension in the obese. *Med Sci Sports Exerc* 1999; **31** (Suppl): S624-S630.
19. Ishikawa K, Ohta T, Zhang J, Hashimoto S, Tanaka H Influence of Age and Gender on Exercise Training Induced BP Reduction in Systemic Hypertension. *The Am J Cardiol* 1999; **84** (2): 192-196. Online publication 2004 : doi.org/10.1016/S0002-9149(99)00233-7.

20. Garrido ALM, Nunes CV, Costa DC, Barreto G dos S, Abreu KF, Pinho LASde, Oliveira LB, Santos MMdos, Pereira PAF: The importance of physical activity in hypertensive subjects. Multidisciplinary Core scientific journal of knowledge. 2017 Edition. 02 year, vol. 03: pp. 17-35, October. ISSN: 0959-2448.
21. Viegas WB, Porpino SKP, Alves NFB, Brito Ade F, Nébrega TKS, & Silva AS. Obesity limits the benefits of exercise in lowering blood pressure in hypertensive. *Revista Brasileira De Ciências Da Saúde* 2010; **14** (1): 121-126.
22. Fagard R, Amery A. Physical exercise in hypertension. In: Laragh JH, Brenner BM, editors. Hypertension: pathophysiology, diagnosis and management, 2nd ed. New York: Raven Press Ltd.; 1995. pp. 2269-2681.
23. Unger T, Borghi C Charchar F, Khan NA, Poulter NR, Prabhakaran D et al 2020 International Society of Hypertension Global Hypertension Practice Guidelines. *Hypertension* 2020; **75**: 1334-1357.
24. Williams B, Mancia G, Spiering W, Agabiti Rosei E, Azizi M, Burnier M, Clement DL, Coca A, de Simone G, Dominiczak A, Kahan T, Mahfoud F, Redon J, Ruilope L, Zanchetti A, Kerins M, Kjeldsen SE, Kreutz R, Laurent S, Lip GYH, McManus R, Narkiewicz K, Ruschitzka F, Schmieder RE, Shlyakhto E, Tsioufis C, Aboyans V, Desormais I; Authors/Task Force Members 2018 ESC/ESH Guidelines for the management of arterial hypertension: The Task Force for the management of arterial hypertension of the European Society of Cardiology and the European Society of Hypertension: The Task Force for the management of arterial hypertension of the European Society of Cardiology and the European Society of Hypertension. *J Hypertens* 2018; **36**: 1953-2041. doi: 10.1097/HJH.0000000000001940.PMID:30234752.
25. Kabanda KG, Mundu MG, Beya BFE, Kiana NN, Nkodila NA, Mety MR, Buila BN, Kayembe NJM, Longo Mbenza B, M'Buyamba-Kabangu JR: Assessment of Cardiovascular Risk Factors Among the Military From the Garrison of Kinshasa in the Democratic Republic of the Congo. *International Review of the Armed Forces Medical Services* 2021; **94**: 33-92 (erratum 94/3 pages).
26. Ross R, de Lannoy L, Stotz PJ. Separate Effects of Intensity and Amount of Exercise on Interindividual Cardiorespiratory Fitness Response. *Mayo Clin Proc* 2015; **90**: 1506-1514.
27. Laterza MC, de Matos LD, Trombetta IC, *et al.* Exercise training restores baroreflex sensitivity in never-treated hypertensive patients. *Hypertension* 2007; **49**:1298-1306.
28. Nelson L, Esler MD, Jennings GL and Korner K Effect of changing levels of physical activity on blood-pressure and haemodynamics in essential hypertension. *Lancet* 1986; **328** :473-476.
29. Kirchheim HR. Systemic arterial baroreceptor reflexes. *Physiol Rev* 1976; **56**:100-176.
30. Felix JVC, Michelini LC. Training-induced pressure fall in spontaneously hypertensive rats is associated with reduced angiotensinogen mRNA expression within the nucleus tractus solitarii. *Hypertension* 2007; **50**:780-785.
31. Mcallister, Adaptations in control of blood flow with training: splanchnic and renal blood flows. *Med Sci Sport Exerc* 1998; **30** : 375-381.
32. Urata H, Tanabe Y, Kiyonaga A, Ikeda M, Tanaka H, Shindo M, Arakawa K Antihypertensive and volume-depleting effects of mild exercise on essential hypertension. *Hypertension* 1987; **9** (3): 245-252 doi: 10.1161/01.hyp.9.3.245.
33. M'Buyamba-Kabangu JR, Fagard R, Lijnen P & Amery A: Relationship between plasma renin activity and physical fitness in normal subjects. *Eur J Appl Physiol* 1985; **53**: 304-307.
34. Rondon MUPB, Alves MJNN, Braga AMFW, Teixeira OTUN, Barretto ACP, Krieger EM, Negrão CE: Postexercise blood pressure reduction in elderly hypertensive patients. *J Am Coll Cardiol* 2002; **39** (4): 676-682 doi: 10.1016/s0735-1097 (01)01789-2.
35. Fagard, R. Effects of exercise, diet and their combination on blood pressure. *J Hum Hypertens* 2005; **19**: S20-S24 doi.org/10.1038/sj.jhh.1001956.

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