Effects of exercise and custom-made orthotics on blood pressure and heart rate variability: a randomized controlled pilot study

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Abstract

Objective: The objective of this study is to use randomized controlled research design to investigate the effect of an exercise program and custom-made flexible orthotics on heart rate variability and blood pressure at varying stages of exercise over a 5-month period.

Methods: Thirteen ping-pong players were recruited and randomly assigned into control and experimental groups. Both groups had the same exercise program, and only the experimental group wore custom-made flexible orthotics. Exercise effects were compared before and after the training using heart rate variability and blood pressure. The study lasted 5 months with 1 data collection per month except in the fourth month.

Results: Ten male players (6 in the experimental group) completed the study. The average age of the participants was 44 ± 16 years. The blood pressure in the experimental group significantly decreased after the 5-month study period and after each exercise session. The blood pressure did not change significantly after each exercise session in the control group. The heart rate was significantly increased immediately after exercise and remained at a higher level after the 20 minutes of rest at the end of each day's exercise session. The average resting heart rate decreased from 69.7 ± 1.708 to 66.8 ± 4.480 ($P < .05$) in the experimental group but increased from 69.7 ± 1.708 to 90.7 ± 2.808 ($P > .05$) in the control group. The total power reflecting the total autonomic activity was significantly decreased immediately after exercise and after the 20-minute rest period at the end of the exercise session in both the control and experimental groups.

Conclusions: There were positive changes in cardiac and vascular autonomic regulations with exercise training when combined with foot orthotics.

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Introduction

Research evidence has suggested that the autonomic nervous system activities are affected by exercise in normal and disease conditions.¹⁻⁴ Questions remain as to how trained athletes' heart rate variability (HRV) and blood pressure (BP) change at different stages of exercise, namely, before, during, and after an exercise program. Because BP is strongly influenced by the autonomic nervous system in daily activities,⁵ it is interesting to investigate the interaction of the autonomic nervous system with BP under an exercise program. It is known that long-term BP is determined by fluid homeostasis.⁵ Short-term BP changes during daily activities are not reliable indicators of BP changes.^{5,6} Therefore, this study was designed to investigate both short-term (1 day) and long-term (5 months) continuous exercise program on BP and HRV in recreational athletes.

There are many studies on the effect of exercise on BP and HRV. Sharma and Deepak⁷ explored the possibility of a short duration of supervised physical training on cardiovascular performance and attempted to look into the changes in the autonomic tone as assessed by HRV. They studied 25 healthy adult male subjects who underwent 15 days of moderate physical training on a bicycle ergometer. Heart rate (HR) and BP response to exercise and during recovery were monitored and autonomic activity (tone) was assessed by HRV in a resting condition, and all the parameters were compared before and after physical training. Heart rate response to graded exercise on the bicycle ergometer showed a significant decrease at the second, third, fifth, and sixth minute during exercise after physical training, and systolic BP response showed a significant decrease at fourth, fifth, and sixth minute during exercise after physical training. They concluded that even a short duration of physical training results in favorable cardiovascular performance and it may be ascribed to autonomic modulation.

Information regarding the effect of a custom-made flexible orthotics on the autonomic nervous system and BP is very limited. However, this area of research is directly related to athletic performance in 2 important aspects. The first is the direct effect of the autonomic nervous system activities on athletic performance, BP and HRV. The second is the comfort of shoes with corrective orthotics that promote athletic performance and reduce existing pain.^{8,9} For the first aspect, no study has documented that custom-made flexible orthotics affect the autonomic nervous system function. For the second aspect, there are many studies

showing improved performance of workers using orthotics but less evidence for athletes.¹⁰⁻¹⁴

The purpose of this study is to use a randomized controlled research design to investigate the effect of an exercise program and custom-made flexible orthotics on HRV and BP at varying stages of exercise. The hypothesis was that exercise and custom-made orthotics have a positive impact on the HRV and BP. Therefore, the null hypothesis was that exercise and custom-made flexible orthotics would not induce positive changes in HRV and BP during the study period.

Methods

Design

This is a randomized controlled study. A random table was used for subject assignment to either the experimental or the control group.¹⁵ Both groups had the same exercise program, and only the experimental group worn custom-made flexible orthotics. The exercise effects were compared before and after the training. This study was approved by the Logan College of Chiropractic Institutional Review Board (Chesterfield, MO). All subjects read and signed institutional review board-approved informed consent documents before they underwent any study-related procedure. No sample size estimate was used in this pilot study because of the size limitation of the sports club.

Subjects

Subjects from different racial, sex, and age groups were recruited in this study. Each subject was a ping-pong club member for the previous 5 years and was an active member in the club. Only subjects who played at least twice a week or no less than 6 hours per week were included. Any individual with coronary heart diseases, serious uncontrolled hypertension, or other diseases, such as osteoporosis, were excluded from the study. All players agreed to participate in the study without monetary compensation.

Method

Heart rate variability

Biocom's (Biocom, Seattle, Wash) Heart Rhythm Scanner was used in the HRV data collection with digital signal processing software. The heart scanner records electrocardiographic (ECG) signal, computing the instantaneous changes of HRV after each recording session. The heart rhythm scanner is an ECG unit that

Fig 1. Study flow chart.

connects the unit to the subjects through 3 small electrodes that attached to the left arm, right arm, and left leg. No additional gels were needed for the electrodes. Special care was given to clean the skin

surface to improve skin conductance. Data cleaning techniques were used to remove noise in the ECG signals to improve the quality of HRV measurements. This included checking each ECG tracing to make sure

Table 1 Five-month BP response before, during, and after exercise in the experimental group

		Experimental Group					
		Before EX		During EX		After EX	
		Systolic	Diastolic	Systolic	Diastolic	Systolic	Diastolic
First Month	Mean	128.000	84.167	119.667	82.333	116.667	83.833
	SD	11.314	3.920	10.614	4.082	9.180	3.488
	<i>t</i>	0.026	0.194			0.025	0.809
Second Month	Mean	122.667	82.833	117.000	81.667	118.333	80.333
	SD	7.659	5.456	5.762	3.670	7.528	1.966
	<i>t</i>	0.137	0.545			0.189	0.286
Third Month	Mean	125.200	84.400	117.200	84.400	113.600	81.600
	SD	10.354	4.336	12.215	6.066	12.837	3.578
	<i>t</i>	0.025	1.000			0.035	0.108
Fifth Month	Mean	121.167	81.667	119.000	81.000	111.667	80.333
	SD	2.041	2.658	1.673	2.449	7.528	4.457
	<i>t</i>	0.108	0.709			0.035	0.328

EX, Exercise.

Table 2 Five-month BP response before, during, and after exercise in the control group

		Control Group					
		Before EX		During EX		After EX	
		Systolic	Diastolic	Systolic	Diastolic	Systolic	Diastolic
First Month	Mean	126.833	83.000	123.500	84.667	126.667	83.667
	SD	14.148	6.293	14.963	6.772	8.733	6.623
	<i>t</i>	0.337	0.185			0.952	0.465
Second Month	Mean	125.333	83.333	121.000	82.333	120.000	84.333
	SD	8.641	5.317	7.127	4.457	6.325	3.882
	<i>t</i>	0.290	0.415			0.170	0.741
Third Month	Mean	124.000	82.000	125.500	80.833	121.333	81.167
	SD	7.899	5.060	10.913	4.834	11.075	5.456
	<i>t</i>	0.479	0.135			0.371	0.259
Fifth Month	Mean	118.333	82.667	114.000	78.000	113.333	77.333
	SD	13.292	5.888	14.859	5.367	13.003	6.282
	<i>t</i>	0.071	0.052			0.042	0.072

that accurate ECG R-R intervals were recorded for HRV analysis.

Blood pressure

BIOPAC (BIOPAC Systems Inc, Goleta, Calif) BP measurement equipment was used for the study. The device uses manual control for BP measurements to reduce instrumental errors.

Custom-made flexible orthotics

All foot orthotics were custom-made first by scanning the subjects' feet in the research laboratory, and necessary information was sent to Foot Levelers (Roanoke, Va) for fabrication. It took about 6 to 8 days to receive the orthotics after the order was made. The custom-made flexible orthotics were fit to Foot Levelers's standard sports shoes for comfort and easy application. This eliminated the need for athletes to fit the orthotics to their own shoes.

Study protocol

The study lasted 5 months with 1 data collection per month except in the fourth month. During each data collection, BP and HRV data were collected 3 times (ie, baseline, between games, after games). The ping-pong club met twice a week on Tuesday and Thursday between 6:30 and 10:00 PM on a regular basis. Each player was allowed 10 minutes of warm-up before competitive play. The baseline HRV and BP were recorded before the warm-up period. After 1 player played with 2 other players, the between-the-game data were collected right after the second game. No rest was allowed for this data collection to detect the peak HR and BP changes. The third data

collection of HRV and BP was at the end of the playing period when all subjects were to have rested for at least 20 minutes to cool off from the games before the data were collected.

Data collection

The data were collected by the researcher on the study site from 6:30 to 10:00 PM regularly on Tuesdays and Thursdays. The manual BP measurements provided reliable readings of the subjects' BP. The HRV recording was an objective reading of the subjects' real-time ECG, which was believed to be reliable. There were no computer crashes or any mechanical damages to any research equipment during the data collection period.

Statistical analysis

All continuous data were expressed as mean $\pm$ SD. Student *t* test was used for comparisons of continuous variables measured in the study. Statistical analysis was performed using SPSS 12 (SPSS Inc,

Fig 2. Blood pressure changes in the experimental group.

Fig 3. Blood pressure changes in the control group.

Chicago, Ill). A probability of less than .05 was considered significant.

Results

Thirteen ping-pong players were recruited and 10 player's data were included in the data analysis (10 male, 6 in the experimental group). Three players left the club because of job transfer or other personal reasons while participating in the study (Fig 1). The average age of the participants was 44 ± 16 years. During the 5-month study period, there were no adverse events that occurred with or without wearing the foot orthotics.

The BP responses before, during, and after exercise in the 5-month study are shown in Tables 1 and 2. The BP in the experimental subjects was significantly decreased after the 5-month study period. Significant BP decrease was observed in the experimental group before, during, and after each exercise session (Fig 2).

The BP did not decrease before, during, and after each exercise session in the control group (Fig 3).

The HRV responses are shown in Tables 3-10. The HR was significantly increased immediately after exercise. Many players' HRs were more than 150 beats per minute immediately after the 2 games and gradually decreased during the 5 minutes of HRV data collection. The decrease of HR during the resting period was uneven between the players. Younger players' HRs decreased faster than older players. Among the older players with similar ages, the decrease in HR was related to the total power of the individual. Subjects with lower total power or a small HRV had slower return of HR. Individuals with higher total power decreased HR faster after exercise. The HR for most players remained at a higher level after the 20 minutes of rest at the end of each day's exercise session. Some players did not show significant HR reduction during the 20-minute rest period. The average resting HR (baseline HR before each data collection) was decreased from 69.7 ± 1.708 to 66.8 ± 4.480 ($P < .05$) in the experimental group but increased from 69.7 ± 1.708 to 90.7 ± 2.808 ($P > .05$) in the control group. The total power reflecting the total autonomic activity was significantly decreased immediately after exercise and after the 20-minute rest period at the end of the exercise session in both the control and experimental groups.

Discussion

The current study was designed to investigate the effect of exercise and custom-made flexible orthotics

Table 3 Heart rate variability of the experimental group in the first month

First Month	Experimental Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	69.700	1.709	106.800	4.613	0.008	86.733	9.834	0.117
Mean RR	861.300	21.328	562.433	24.188	0.006	697.900	82.071	0.103
SDNN	53.967	15.653	36.900	4.900	0.287	32.333	16.772	0.296
RMS-SD	37.300	4.453	16.070	6.109	0.059	22.600	12.917	0.218
Total Power	822.400	358.289	68.567	22.743	0.062	495.233	622.474	0.576
VLF	306.700	149.266	26.167	5.248	0.087	159.367	177.479	0.512
LF	367.167	170.553	31.100	18.460	0.062	291.833	410.820	0.791
HF	148.500	98.144	11.300	2.740	0.131	44.067	34.683	0.265
LF Norm	71.733	7.267	69.367	14.545	0.778	75.933	12.889	0.394
HF Norm	28.267	7.267	30.700	14.660	0.774	24.067	12.889	0.394
LF/HF	2.700	1.127	2.700	1.400	1.000	4.533	3.980	0.384

RR, R-R interval; SDNN, SD of the normal-to-normal heartbeats; RMS, root mean squared; VLF, very low frequency; LF, low frequency; HF, high frequency; Norm, normalized.

Table 4 Heart rate variability of the experimental group in the second month

Second Month	Experimental Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	71.100	4.457	95.960	17.534	0.028	85.650	7.566	0.327
Mean RR	846.740	56.027	642.060	116.272	0.009	703.550	62.296	0.316
SDNN	47.200	6.256	33.340	10.062	0.222	33.350	9.122	0.100
RMS-SD	35.875	9.936	21.620	9.673	0.183	37.400	17.253	0.608
Total Power	620.250	132.641	205.720	178.776	0.046	239.900	91.217	0.053
VLF	360.375	114.015	118.220	105.503	0.090	54.950	30.618	0.280
LF	184.975	95.149	57.980	49.501	0.047	103.600	36.204	0.254
HF	74.875	43.573	29.500	25.605	0.297	81.350	85.631	0.546
LF Norm	68.325	16.541	68.040	9.795	0.929	63.300	22.203	0.358
HF Norm	31.675	16.541	31.960	9.795	0.929	36.700	22.203	0.358
LF/HF	2.900	1.917	2.440	1.448	0.860	2.350	2.051	0.049

in athletes who perform exercise on regular basis over a 5-month period. The null hypothesis was that exercise and orthotics had no effect on BP and HRV. The study rejected the null hypothesis by demonstrating significant decreases in BP and HRV before, during, and after the exercise program with foot orthotics in the experimental group. No significant BP changes were observed in the control group. Significant increase in resting HRV was seen in the experimental group.

The reason behind selecting the 5-month study period was to allow the players to respond to the exercise program and the new orthotics to influence the autonomic nervous system activities. It has been reported by Loimaala et al,¹⁶ Perini et al,¹⁷ and Stein

et al¹⁸ that short-term aerobic training had no effects on resting cardiac autonomic modulation in older people. A study by Iwasaki et al¹⁹ suggested a short-term positive effect of exercise training on HRV showing an increase at 3- and 6-month time points of regular training with an even decrease at 9 and 12 months. Uusitalo et al²⁰ performed a 5-year study on exercise and HRV with 1 data collection per year. They found beneficial cardiovascular and autonomic effect.

Potential confounding factors, such as medication, diseases, and smoking, could have a strong effect on HRV and BP, which could cover the effect of physical activity and orthotics. In this study, all subjects were not taking any medications during the entire study period, none smoked cigarettes, and none had known

Table 5 Heart rate variability of the experimental group in the third month

Third Month	Experimental Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	66.800	4.480	101.525	6.663	0.006	93.550	4.273	0.002
Mean RR	901.425	60.979	592.825	37.175	0.006	642.300	29.380	0.003
SDNN	62.175	20.663	33.325	3.195	0.067	33.150	9.112	0.111
RMS-SD	37.875	10.135	13.850	10.414	0.069	25.975	6.589	0.182
Total Power	1228.200	705.731	161.925	146.018	0.066	265.375	191.254	0.098
VLF	575.525	252.195	70.575	43.490	0.029	114.625	110.537	0.075
LF	527.100	384.792	68.950	73.431	0.110	112.100	63.155	0.117
HF	125.525	80.131	22.375	34.695	0.136	38.575	33.418	0.185
LF Norm	78.875	6.035	83.025	9.414	0.492	75.250	7.942	0.508
HF Norm	21.100	6.067	16.975	9.414	0.495	24.750	7.942	0.506
LF/HF	4.025	1.307	6.125	3.135	0.208	3.475	1.861	0.653

Table 6 Heart rate variability of the experimental group in the fifth month

Fifth Month	Experimental Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	75.517	11.303	104.483	16.036	0.001	95.000	14.027	0.023
Mean RR	811.350	137.696	585.167	85.783	0.001	642.660	92.990	0.019
SDNN	47.150	13.036	51.017	46.899	0.870	32.360	13.230	0.202
RMS-SD	33.700	15.620	54.350	70.008	0.538	24.420	13.985	0.330
Total Power	566.017	315.657	265.033	419.101	0.313	348.000	243.786	0.401
VLF	234.500	141.543	143.200	227.547	0.523	177.400	197.433	0.629
LF	261.117	175.158	72.200	110.187	0.125	134.140	95.474	0.252
HF	70.417	37.963	49.583	81.919	0.654	36.440	47.250	0.334
LF Norm	76.400	8.389	62.033	9.615	0.095	83.200	9.743	0.362
HF Norm	23.583	8.386	37.967	9.615	0.094	16.740	9.746	0.354
LF/HF	3.983	2.751	1.800	0.727	0.162	6.300	3.029	0.384

cardiovascular diseases. In addition, all members of the current study performed the same level of exercise for at least 5 years, which reduced nonhomogeneity in their former activity levels. Because all subjects played the same sport during the study period, the effect of physical activity was more consistent than in a heterogeneous study¹⁶ of different levels and kinds of exercises. Therefore, all these factors strengthened the current study.

The present study used 5-minute ECG recording for HRV analysis, which was a short-term recording compared with 24-hour recording. Goldsmith et al^{21,22} measured 24-hour recordings, whereas others measure short recordings of at least 5 minutes. Some randomized longitudinal exercise training studies have used

24-hour HRV.^{16,23-25} There are only 2 randomized exercise training interventions using short-term HRV recordings reported.^{26,27} Among the randomized longitudinal studies,^{16,23-27} a positive effect of aerobic training on daytime HRV has been found in 3 studies,²³⁻²⁵ all using 24-hour recordings. In the other randomized studies, significant effects have not been found, even with a significant increase in maximal aerobic capacity. In addition, none of the randomized longitudinal studies found a significant effect on nighttime HRV. Some of the nonrandomized studies using short-term HRV recordings have found a positive effect of exercise training on HRV.^{19,28} Many studies have reported the changes of HRV in relation to athletic activities.²⁹⁻³⁵

Table 7 Heart rate variability of the control group in the first month

First Month	Control Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	69.700	1.709	117.567	4.891	0.031	100.767	7.304	0.185
Mean RR	861.300	21.328	510.800	20.756	0.040	597.500	41.830	0.177
SDNN	53.967	15.653	36.700	12.950	0.821	21.267	11.296	0.431
RMS-SD	37.300	4.453	16.733	8.776	0.086	14.800	8.107	0.196
Total Power	822.400	358.289	44.600	12.401	0.162	122.000	138.609	0.352
VLF	306.700	149.266	27.633	17.789	0.236	31.367	22.912	0.281
LF	367.167	170.553	9.133	6.028	0.199	77.700	102.561	0.794
HF	148.500	98.144	7.800	6.056	0.157	12.933	13.271	0.304
LF Norm	71.733	7.267	52.567	33.739	0.634	81.300	5.575	0.179
HF Norm	28.267	7.267	47.433	33.739	0.634	18.700	5.575	0.179
LF/HF	2.700	1.127	3.500	5.200	0.706	4.733	1.986	0.214

Table 8 Heart rate variability of the control group in the second month

Second Month	Control Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	79.100	7.661	106.525	11.281	0.010	102.150	1.768	0.185
Mean RR	763.550	71.020	568.025	61.217	0.010	587.600	10.324	0.235
SDNN	40.400	12.147	20.450	6.011	0.094	28.500	3.111	0.256
RMS-SD	28.475	3.550	15.400	8.730	0.114	15.350	10.960	0.473
Total Power	475.600	340.010	84.575	108.809	0.111	99.750	9.546	0.349
VLF	217.175	205.756	22.525	21.053	0.158	56.550	42.639	0.180
LF	196.500	120.124	51.000	84.403	0.061	31.450	20.294	0.408
HF	61.925	37.776	11.025	6.917	0.102	11.750	12.799	0.313
LF Norm	75.000	5.855	65.025	30.745	0.531	77.600	12.587	0.550
HF Norm	25.000	5.855	34.975	30.745	0.531	22.400	12.587	0.550
LF/HF	3.200	1.143	5.825	6.033	0.414	4.300	2.970	0.500

Blood pressure was significantly decreased over the 5-month study period. This finding was not seen in the study of Uusitalo et al.²⁰ Radaelli et al.²⁹ found an increase in sympathetic modulation of peripheral vessels with aerobic training in patients with chronic heart failure but not in healthy controls. Recent studies shown different response of moderate exercise training¹⁹ compared with heavy training in healthy athletes in BP variability.³⁰ It has been hypothesized by researchers²⁰ that BP changes associated with exercise training could result in vascular remodeling through adaptation of endothelium and smooth muscle¹⁹ rather than changes in vasomotor activity.

The orthotics seemed to assist players enhance the exercise program to achieve beneficial changes in BP

and HRV. The significant BP decreases were only observed in the experimental group with orthotics. Because of the small sample size, the results were not conclusive. It only points to the positive direction for combining comfortable orthotics with an exercise program. In personal communication with club members, they all reported that the orthotics were comfortable to wear during exercise as well as during regular non-exercise period. This correlates with previously documented feedback.^{12-14,36,37} Because the orthotics used in the study were fitted into sports shoes, the break-in period was shortened for comfortable game wearing. There were 2 areas of improvement needed in the orthotics as noted by the participants. One suggestion was to use softer leather for athletic shoes for greater comfort and the second was to strengthen the shoe

Table 9 Heart rate variability of the control group in the third month

Third Month	Control Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	90.700	2.828	114.250	12.657	0.183	106.550	5.020	0.062
Mean RR	661.950	20.435	528.300	58.548	0.127	563.600	26.446	0.027
SDNN	32.150	0.212	24.800	1.273	0.090	29.750	3.323	0.472
RMS-SD	22.700	0.849	15.300	10.182	0.517	14.100	10.465	0.477
Total Power	386.400	223.021	92.850	94.116	0.192	294.900	65.902	0.561
VLF	140.250	100.904	53.300	55.013	0.227	163.050	113.632	0.239
LF	206.100	107.480	34.050	40.941	0.170	116.250	34.719	0.536
HF	39.950	14.637	5.450	1.768	0.206	15.600	13.011	0.431
LF Norm	83.200	2.404	68.550	35.709	0.646	89.250	6.010	0.254
HF Norm	16.800	2.404	31.450	35.709	0.646	10.750	6.010	0.254
LF/HF	5.000	0.849	7.950	10.112	0.731	10.050	6.152	0.407

Table 10 Heart rate variability of the control group in the fifth month

Fifth Month	Control Group							
	Before		During			After		
	Mean	SD	Mean	SD	<i>t</i>	Mean	SD	<i>t</i>
Heart Rate	75.425	5.309	106.200	8.283	0.002	92.800	6.280	0.000
Mean RR	798.400	56.651	567.525	44.571	0.001	648.800	45.556	0.000
SDNN	45.000	11.265	34.700	3.477	0.089	33.650	12.600	0.101
RMS-SD	24.375	12.654	19.225	9.506	0.622	19.050	5.807	0.373
Total Power	824.050	494.609	103.700	53.225	0.051	458.525	415.737	0.003
VLF	562.275	327.365	31.450	14.445	0.044	210.500	181.828	0.037
LF	216.450	154.426	47.325	33.125	0.080	226.250	231.452	0.909
HF	45.275	39.088	24.950	33.531	0.501	21.575	21.520	0.093
LF Norm	82.725	10.387	69.650	23.898	0.289	88.125	7.771	0.584
HF Norm	17.275	10.387	30.350	23.898	0.289	11.875	7.771	0.584
LF/HF	7.250	6.094	4.550	4.227	0.546	10.000	5.943	0.670

rubber adhesives, which loosened after 5 months of wear in 1 player's shoes.

The present study has some limitations. The most obvious was the small sample size, which was because of the small size of the sports club. Another factor that may potentially affect the results of the study was lack of blinding. This factor was minimized by using objective HRV analysis and reliable BP measurements. Another limitation is the cooling-off period used in the study for each day's final data collection. It was desirable to rest longer than 20 minutes after the final game to observe the return of HR to resting state. This answers the question of how much time is needed for a complete recovery from an exercise program. In this study, the exercise ended late at night, so it was impossible to extend the cooling period for the data collection sessions. Therefore, this 20-minute cooling-off period was chosen by compromise. It was noted in the study that many players' HR were still 10 to 30 beats higher than the resting baseline heartbeats.

Conclusion

The present randomized controlled pilot study of exercise and orthotics showed a significant decrease in BP and increase in HRV over the 5-month study period. The study demonstrated a potential benefit of combining exercise with orthotics to improve cardiovascular health in recreational athletes.

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