平成 25 年度～平成 27 年度
森林浴による健康増進等に関する調査研究
報 告 書

公益財団法人 車両競技公益資金記念財団

目　　次

はじめに

近年、世界的に温暖化や経済活動によって多くの緑が消えていく中、我が国は国土の３分の２が森林という森林率では先進国の中で３番目の森林大国です。このように豊かな森林資源を持つ日本で 1982 年に林野庁によって提唱された「森林浴」は、その後、健康志向と相まって森林浴ブームを巻き起こしました。

当初、森林浴はその効用について医学的データが少なく、客観的な根拠が整っていませんでしたが、2001 年以降、人の生理的反応を医学的に計測し、評価する技法が飛躍的に進み、森林浴がもたらす生体反応を①座位、歩行時のストレスホルモンや心拍変動②血中の抗ガンタンパク質の変化等で読み取り、森林浴の効果を解明していくことが可能となりました。

これまでのデータ蓄積によって森林セラピーが生み出す生理的効果は明らかになってきていますが、これらのデータの多くは 20 代の健康な男性において取得されたものであり、もっとも森林セラピーが必要と考えられる半健康人、境界域高血圧、境界域糖尿病、肥満等の未病状態の人間におけるデータの蓄積は皆無に近いのが現状であります。

そこで、私ども車両競技公益資金記念財団は「森林浴による健康増進等に関する調査研究委員会」を設置し、平成 25 年度より３年計画でデータ蓄積が少ない中高年・高血圧者・男性、中高年・女性を被験者として森林セラピーの生理的、心理的リラックス効果についてデータ収集を進め、その効果について検討致しました。

この度、３年間の成果を報告書という形で取りまとめましたので、研究機関の皆様にお配りすることと致しました。

本報告書が皆様の森林浴による健康増進に関する研究の一助となれば幸いです。

平成２８年３月

公益財団法人　車両競技公益資金記念財団
理 事 長　　横　山　和　夫

平成25年度
森林浴による健康増進等に関する調査研究
報告書

千葉大学環境健康フィールド科学センター
宮崎良文

目次

はじめに

日本において、実質的な森林セラピー研究が始まり、約10年が経過し、多くの生理データが蓄積されてきた。これまでの森林セラピー研究においては、宮崎良文が中心となり、600名を越える生理的リラックス効果に関するデータが提出されており、これは世界に類を見ない傑出した科学的蓄積と言えよう。加えて、李卿が中心となり、免疫機能改善効果に関する極めて学術的レベルの高いデータも提出されており、多くの注目を集めている。

一方、森林セラピーによる600名を越える生理的リラックス効果に関するデータは20代の健康な男性を中心として、都市における活動との差異を中心として蓄積されてきた。しかし、社会への還元を念頭においた場合、半健康人、未病状態にある方々におけるデータ、の蓄積が求められているのが現状である。

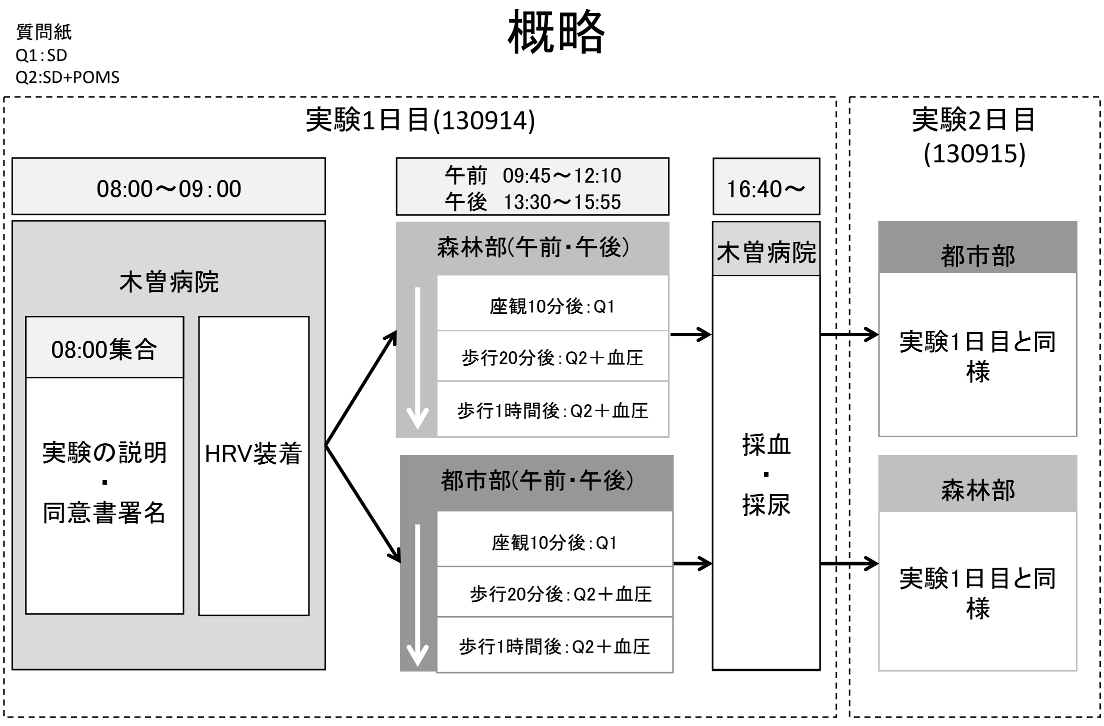
本研究の目的は、「未病者」への森林セラピー効果の解明を行うことである。

Ⅰ 森林浴2日タイプ実験

（1）方法

1）実験デザイン

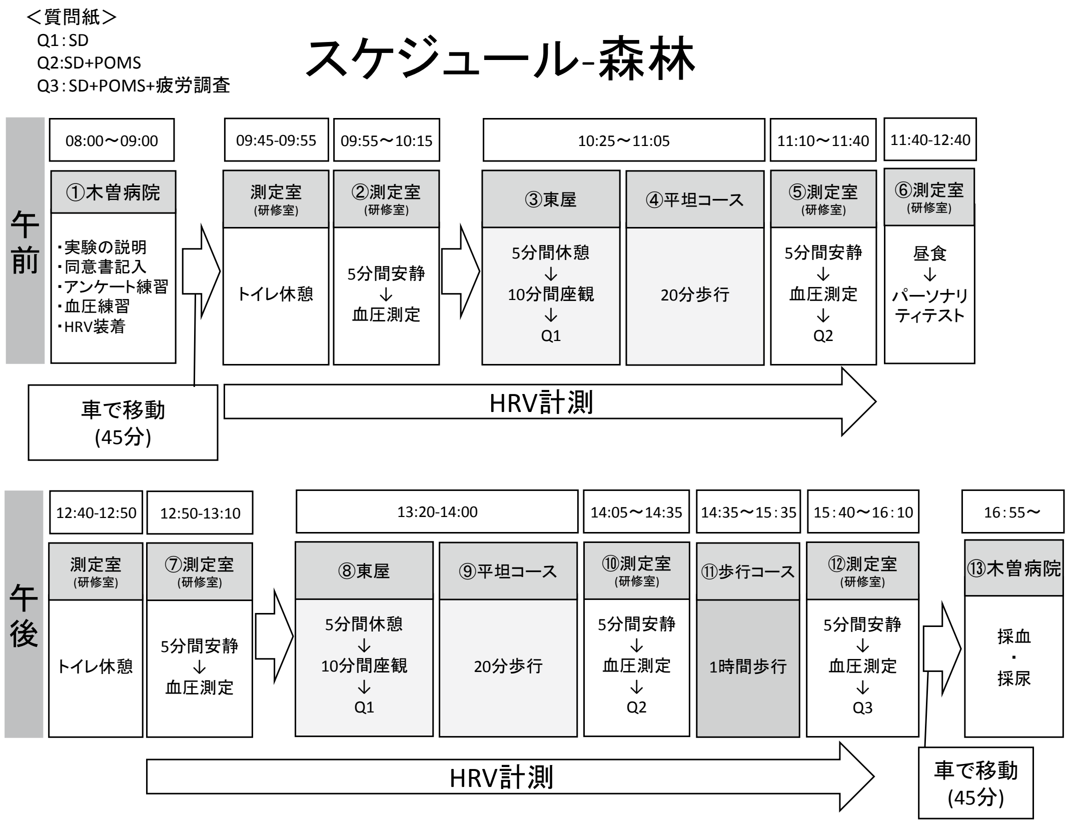
以下に実験デザインの概略を示す。被験者を2群に分け、1日目、第１群は森林部に行って森林浴を行い、第２群は対照としての都市部に行って、同じ運動量にて同じ歩行、座観を行う。２日目は異なる実験地に行って歩行、座観実験を実施する。



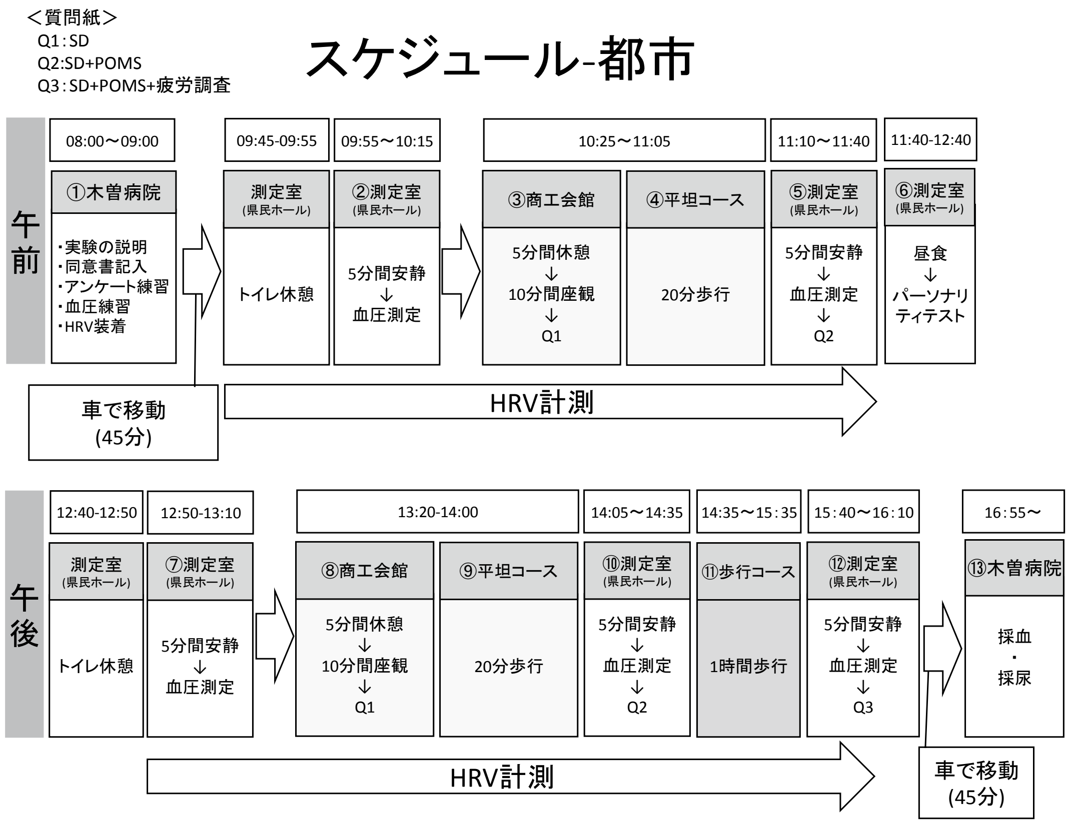
以下に、森林部における実験スケジュールの詳細を示す。

2 日間の実験デザインとし、1 日目、2 日目の森林部ならびに都市部滞在時における 15〜30 分間の座観ならびに 15〜30 分間の歩行時に計測する。

座観、歩行は午前、午後に実施し、計4回の計測を行う。さらに、午後の歩行実験終了後、60分の森林セラピープログラムを実施する。



以下に部における実験スケジュールの詳細を示す。スケジュールは森林部と同様とした。



森林部

座観①

森林部

座観②

森林部

座観③

都市部

座観①

都市部

座観②

都市部

座観③

森林部

歩行①

森林部

歩行②

森林部

歩行③

森林部

歩行④

都市部

歩行①

都市部

歩行②

都市部

歩行③

都市部

歩行④

森林部

血圧測定

都市部

血圧測定

Ⅰ　森林浴2日タイプ実験

（1）方法

2）被験者情報

以下に被験者情報一覧を示す。

長野県立木曽病院に通院中の高血圧・未病状態の方々とし、被験者は中高年・高齢男性21名とした。

木曽病院実験2日タイプ　被験者情報

	年齢(歳)	身長(cm)	体重(kg)
平均	57.2	168.0	66.6
SD	11.0	6.1	10.6

					パーソナリティ別		
被験者No	年齢(歳)	身長(cm)	体重(kg)	年齢別	KG式	STAI	血圧別
1	40	168	51	40代	typeB	high	高血圧群
2	41	171	77	40代	typeB	low	正常高値血圧以下群
3	44	184	71	40代	typeA	high	正常高値血圧以下群
4	44	166	56	40代	typeA	normal	正常高値血圧以下群
5	46	170	55	40代	typeB	normal	正常高値血圧以下群
6	47	173	65	40代	typeB	normal	高血圧群
7	49	166	75	40代	typeB	normal	正常高値血圧以下群
8	47	170	63	40代	typeB	normal	正常高値血圧以下群
9	57	172.5	85	50代以上	typeB	normal	正常高値血圧以下群
10	54	172.5	67	50代以上	typeB	low	正常高値血圧以下群
11	59	169	76	50代以上	typeB	high	高血圧群
12	62	170	67	50代以上	typeB	normal	正常高値血圧以下群
13	65	172	78	50代以上	typeB	high	高血圧群
14	65	156	49	50代以上	typeA	high	高血圧群
15	66	171	85	50代以上	typeA	low	高血圧群
16	66	157	65	50代以上	typeB	normal	高血圧群
17	67	163	60	50代以上	typeA	low	高血圧群
18	70	163	52.5	50代以上	typeB	high	高血圧群
19	69	169	75	50代以上	typeB	high	正常高値血圧以下群
20	71	162	65	50代以上	typeB	normal	高血圧群
21	72	164	61.5	50代以上	typeB	normal	正常高値血圧以下群

年齢		KG式		STAY特性不安		血圧群	
40代	50代以上	typeA	typeB	high	normal/low	高血圧群	正常高値血圧以下群
8	13	5	16	7	14	10	11

Ⅰ　森林浴2日タイプ実験

（1）方法

3）測定手法

森林セラピー用の実験地は、赤沢自然休養林とし、比較のための対象地は伊那市と都心部とした。

測定指標は、心拍変動性（毎分計測）、心拍数（毎秒計測）、血圧（刺激前後計測）、血液指標（メタボリックシンドロームと関連の深いアディポネクチン、ストレス状態を反映するカテコールアミンを含めた約 20 項目）とした。

(2) 結果と考察

1) 座観実験

①午前座観実験

下記に示すように午前中の 10 分間の座観によって、心拍変動性、副交感神経活動には有意差は認められなかった。

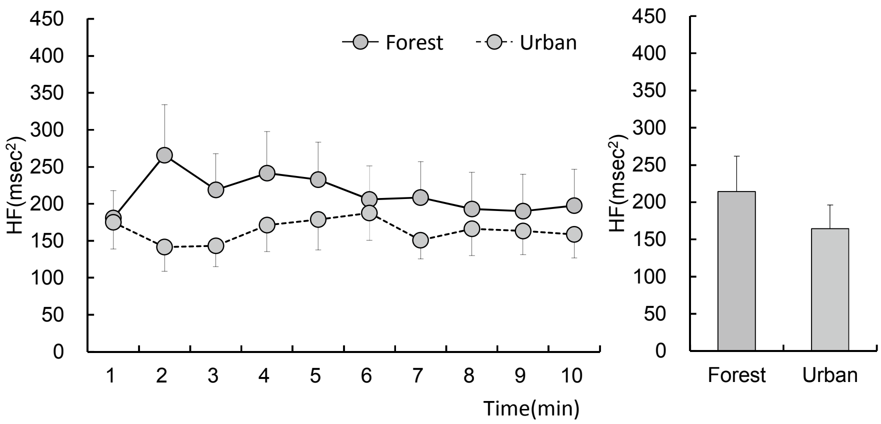
木曽病院実験2日タイプ

			HF	LF/HF	HR
午前	座観		有意差なし	有意差なし	有意差なし
午前	歩行(対数化)		p=0.031 有意差あり(5%)	有意差なし	p=0.001 有意差あり(1%)
午後	座観		p=0.018 有意差あり(5%)	有意差なし	p=0.008 有意差あり(1%)
午後	歩行		有意差なし	有意差なし	p=0.001 有意差あり(1%)
午後	1時間歩行	前半上り	有意差なし	p=0.003 有意差あり(1%)	p=0.000 ※逆転 有意差あり(1%)
午後	1時間歩行	後半下り	有意差なし	有意差なし	p=0.000 有意差あり(1%)

N=21 (平均年齢±標準偏差, 57.2 ± 11.0歳), t検定(対応あり・片側)

午前座観　HF

全体



N=19-20, mean±SE, t検定(対応あり・片側)

そこで、高血圧群と正常高値血圧以下群に分けて整理したところ、高血圧群において、森林浴によって、有意に副交感神経活動が高まり、生理的にリラックスすることが明らかとなった。

血圧別
(高血圧群、正常高値血圧以下群)

木曽病院実験2日タイプ

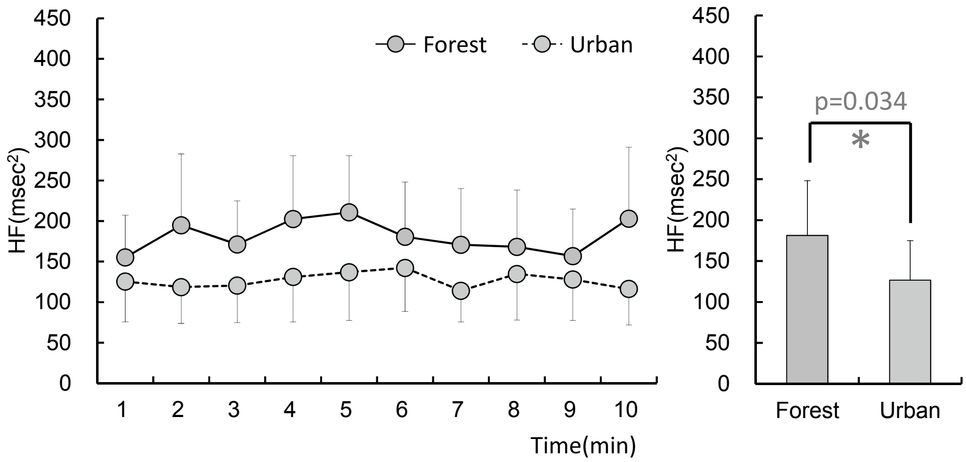
			HF		LF/HF		HR	
			高血圧群	正常高値血圧以下群	高血圧群	正常高値血圧以下群	高血圧群	正常高値血圧以下群
午前	座観		p=0.034 有意差あり (5%)	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし
午前	歩行		有意差なし	有意差なし	有意差なし	有意差なし	p=0.008 有意差あり (1%)	有意差なし
午後	座観		p=0.042 有意差あり (5%)	有意差なし	有意差なし	有意差なし	p=0.006 有意差あり (1%)	有意差なし
午後	歩行		有意差なし	有意差なし	有意差なし	有意差なし	p=0.005 有意差あり (1%)	p=0.041 有意差あり (5%)
午後	1時間歩行	前半上り	有意差なし	有意差なし	有意差なし	p=0.006 有意差あり (1%)	p=0.017 有意差あり (5%)※逆転	p=0.007 有意差あり (1%)※逆転
午後	1時間歩行	後半下り	有意差なし	有意差なし	有意差なし	有意差なし	p=0.000 有意差あり (1%)	p=0.000 有意差あり (1%)

高血圧群 N=10, 正常高値血圧以下群 N=11, t検定(対応あり・片側)

血圧別

午前座観　HF

高血圧群

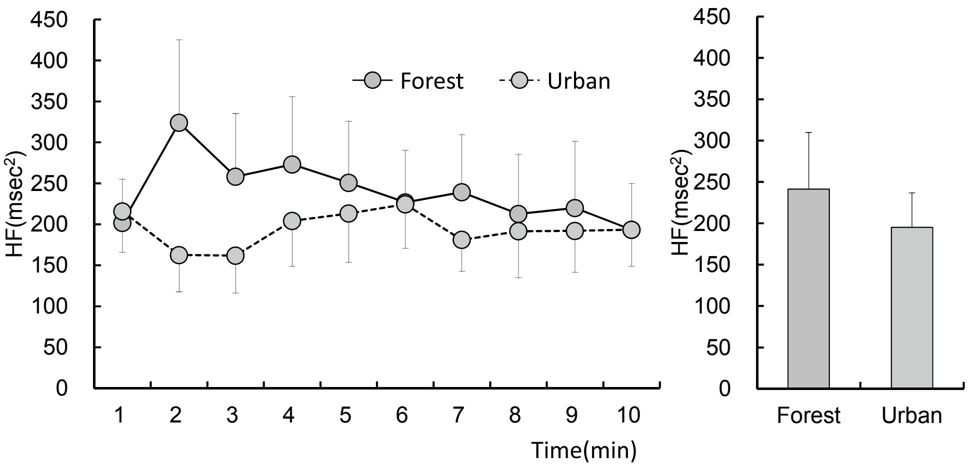


高血圧群 N=10, mean±SE, *:p<0.05, t検定(対応あり・片側)

血圧別

午前座観　HF

正常高値血圧以下群



正常高値血圧以下群 N=11, mean±SE, t検定(対応あり・片側)

結論として、
森林部午前座観（10 分間）は、都市部座観に比べ、
1）副交感神経活動（心拍変動性）に有意差を認めなかった。
2）高血圧群（140mmHg 以上、10 名）と正常高値血圧以下群（139mmHg 以下、11 名）に分けて検討したところ、高血圧群においては、副交感神経活動の有意な昂進を認めた。

つまり、森林部午前座観における副交感神経活動は全体としては有意差を認めないが、高血圧群においては、有意に昂進し、生理的にリラックスすることが分かった。

（2）結果と考察

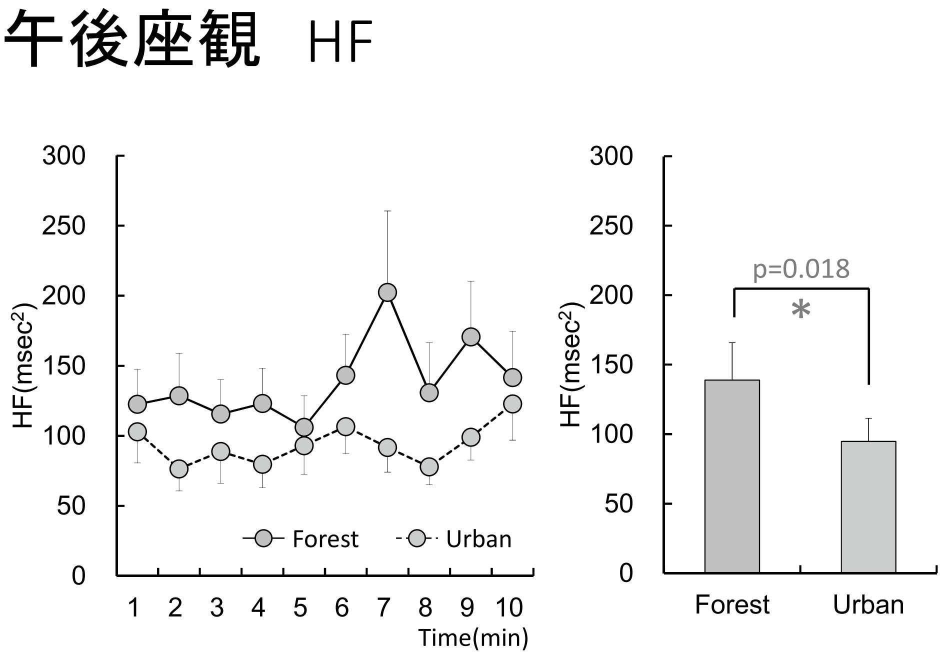
1）座観実験

②午後座観実験

1．全体評価

下記に示すように午後の 10 分間の森林座観によって、心拍変動性における副交感神経活動は有意に高まり、心拍数は有意に低下することが分かった。

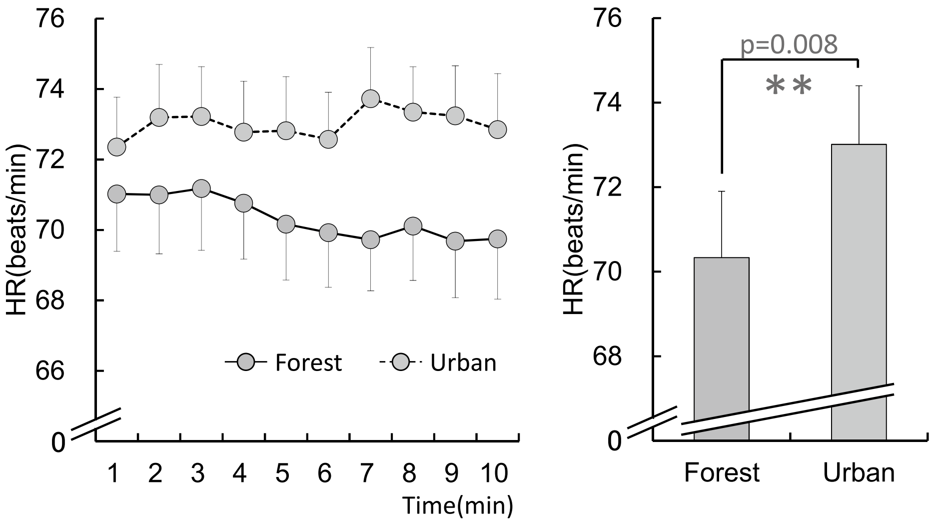
以下に午後の 10 分間の森林座観による副交感神経活動の経時的変化を示す。



N=19-20, mean±SE, ＊: $p<0.05$, t検定(対応あり・片側)

以下に午後の 10 分間の森林座観による心拍数の経時的変化を示す。

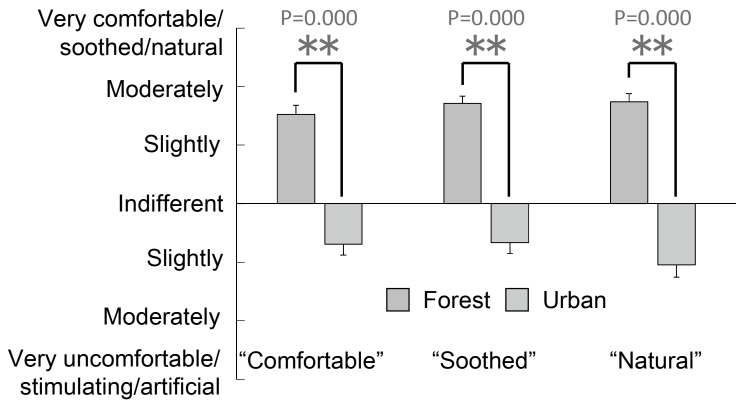
午後座観　HR



N=21, mean±SE, **: p<0.01, t検定(対応あり・片側)

以下に午後の 10 分間の森林座観後の簡易 SD 法（「快適感」「鎮静間」「自然感」）を示す。森林浴によって、快適で、鎮静的で、自然であると感じられていることが明らかとなった。

主観評価　簡易SD法



N=21, mean±SE, **: p<0.01, ウィルコクソン符号付順位和検定(片側)

以上より、森林部午後座観（10 分間）は、都市部座観に比べ、
1）生理的には
①副交感神経活動（心拍変動性）を高めること
②心拍数を減少させること
2）心理的には
①「快適感」「鎮静感」「自然感」を高めること
が明らかとなった。

結論として、午後の森林部座観は生理的・心理的にリラックス状態をもたらすことが分かった。

（2）結果と考察

1）座観実験

②午後座観実験

2. 高血圧・正常高値血圧以下別評価

下記に示すように、午後の 10 分間の森林座観について、高血圧群と正常高値血圧以下群に分けた場合、心拍変動性における副交感神経活動は高血圧群において、有意に高まり、心拍数は有意に低下することが分かった。

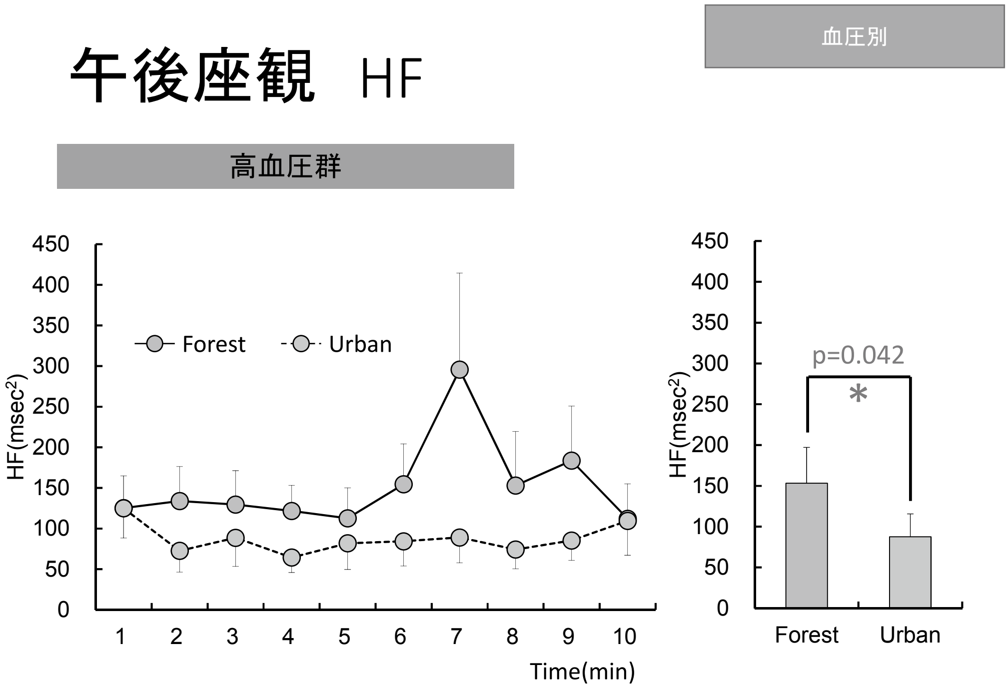
血圧別
(高血圧群、正常高値血圧以下群)

木曽病院実験2日タイプ

			HF		LF/HF		HR	
			高血圧群	正常高値血圧以下群	高血圧群	正常高値血圧以下群	高血圧群	正常高値血圧以下群
午前	座観		p=0.034 有意差あり (5%)	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし
午前	歩行		有意差なし	有意差なし	有意差なし	有意差なし	p=0.008 有意差あり (1%)	有意差なし
午後	座観		p=0.042 有意差あり (5%)	有意差なし	有意差なし	有意差なし	p=0.006 有意差あり (1%)	有意差なし
午後	歩行		有意差なし	有意差なし	有意差なし	有意差なし	p=0.005 有意差あり (1%)	p=0.041 有意差あり (5%)
午後	1時間歩行	前半上り	有意差なし	有意差なし	有意差なし	p=0.006 有意差あり (1%)	p=0.017 有意差あり (5%)※逆転	p=0.007 有意差あり (1%)※逆転
午後	1時間歩行	後半下り	有意差なし	有意差なし	有意差なし	有意差なし	p=0.000 有意差あり (1%)	p=0.000 有意差あり (1%)

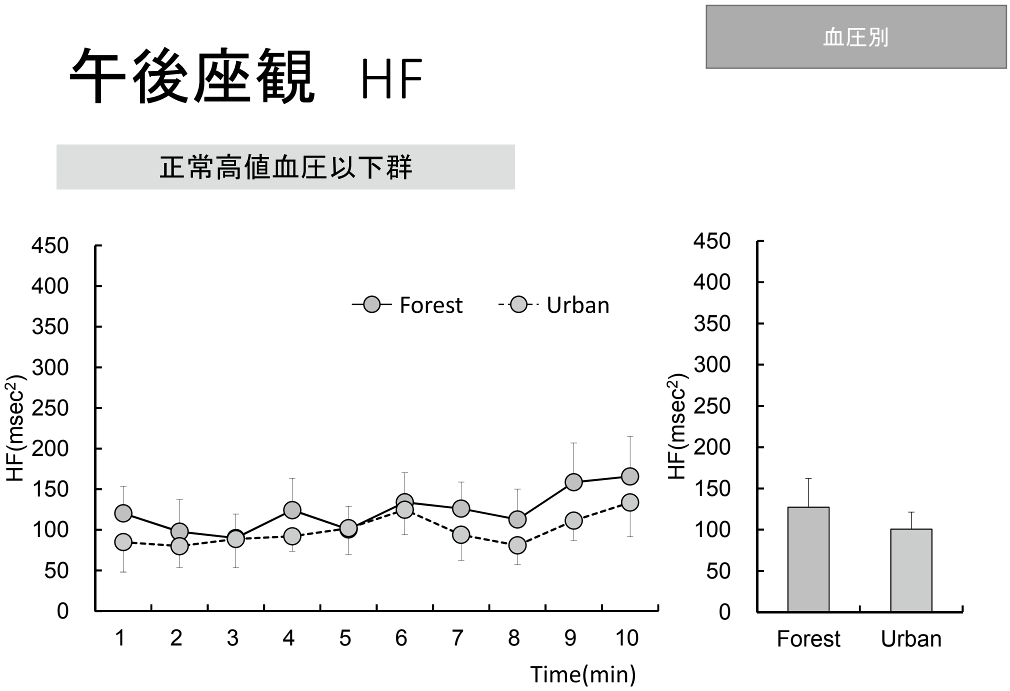
高血圧群 N=10,正常高値血圧以下群 N=11, t検定(対応あり・片側)

以下に、高血圧群における午後の 10 分間の森林座観による副交感神経活動の経時的変化を示す。森林群において副交感神経活動が有意に高まる事が明らかとなった。



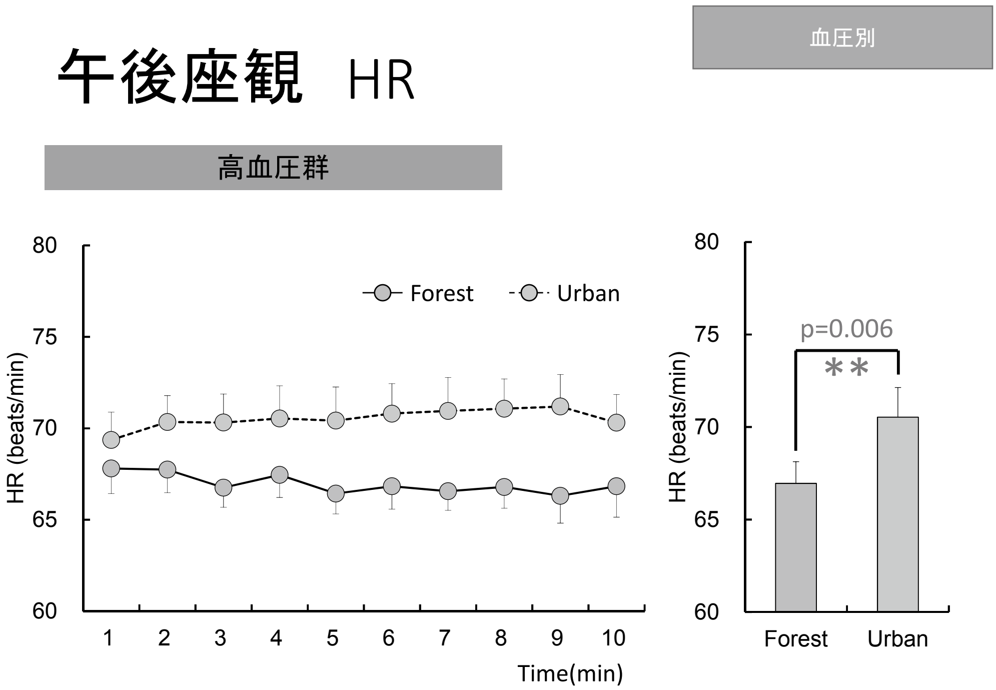
高血圧群 N=10, mean±SE, *:p<0.05, t検定(対応あり・片側)

以下に、正常高値血圧以下群における午後の 10 分間の森林座観による副交感神経活動の経時的変化を示す。副交感神経活動に差異は見られなかった。



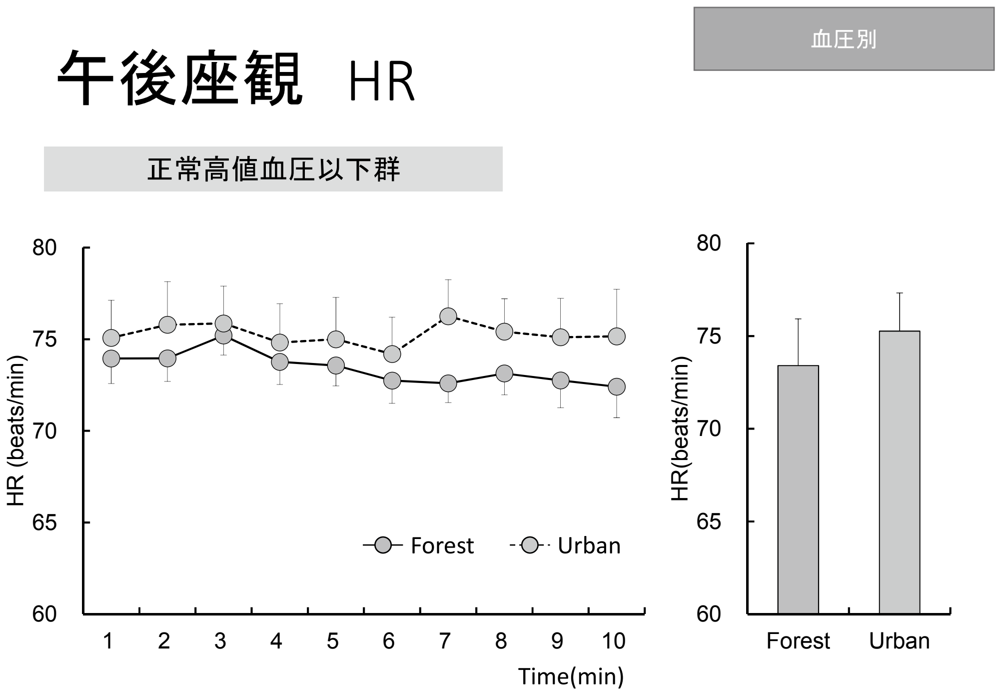
正常高値血圧以下群 N=11, mean±SE, t検定(対応あり・片側)

以下に、高血圧群における午後の 10 分間の森林座観による心拍数の経時的変化を示す。森林群において心拍数が有意に低下する事が明らかとなった。



高血圧群 N=10, mean±SE, **:p<0.01, t検定(対応あり・片側)

以下に、正常高値血圧以下群における午後の 10 分間の森林座観による心拍数の経時的変化を示す。心拍数に差異は認められなかった。



正常高値血圧以下群 N=11, mean±SE, t検定(対応あり・片側)

以上より、森林部午後座観（10 分間）は、都市部座観に比べ、

1）副交感神経活動（心拍変動性）を高め、心拍数を減少させること

2）高血圧群（140mmHg 以上、10 名）と正常高値血圧以下群（139mmHg 以下、11 名）に分けて検討したところ、

①高血圧群においては、副交感神経活動の昂進と心拍数の減少に有意差が認められたが、正常高値血圧以下群においては有意差は認められないこと

が明かとなった。

結論として、森林部座観は高血圧群においては、生理的リラックス効果があるが、正常高値血圧以下群においては効果がないことが分かった。

(2) 結果と考察

1) 歩行実験

①午前歩行実験

下記に示すように、午前の 17 分間の森林歩行において、心拍変動性における副交感神経活動は有意に高まり、心拍数は有意に低下することが分かった。

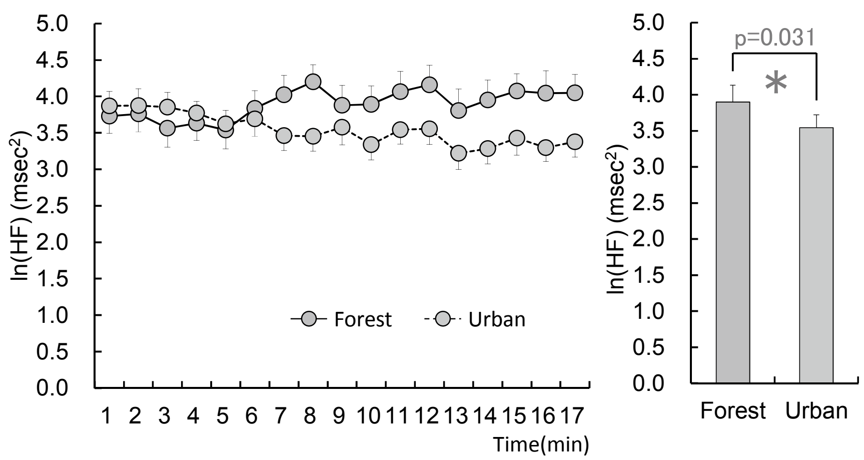
木曽病院実験2日タイプ実験

			HF	LF/HF	HR
午前	座観		有意差なし	有意差なし	有意差なし
午前	歩行(対数化)		p=0.031 有意差あり(5%)	有意差なし	p=0.001 有意差あり(1%)
午後	座観		p=0.018 有意差あり(5%)	有意差なし	p=0.008 有意差あり(1%)
午後	歩行		有意差なし	有意差なし	p=0.001 有意差あり(1%)
午後	1時間歩行	前半上り	有意差なし	p=0.003 有意差あり(1%)	p=0.000 ※逆転 有意差あり(1%)
午後	1時間歩行	後半下り	有意差なし	有意差なし	p=0.000 有意差あり(1%)

N=21 (平均年齢±SD, 57.2 ± 11.0歳), t検定(対応あり・片側)

以下に午前 17 分間の森林歩行による副交感神経活動の経時的変化を示す。

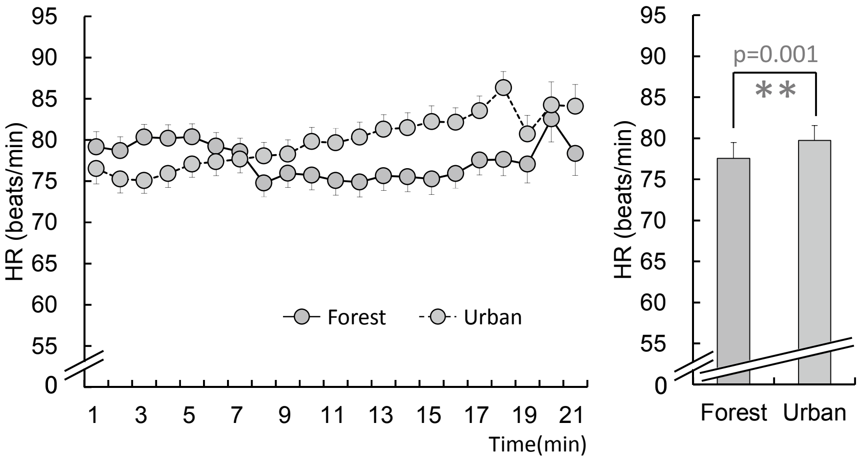
午前歩行 ln(HF)



N=17-20, mean±SE, *:p<0.05, t検定(対応あり・片側)

以下に午前 17 分間の森林歩行による心拍数の経時的変化を示す。

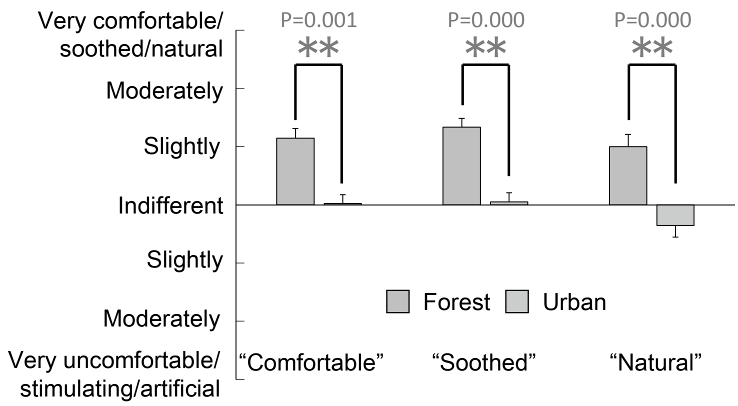
午前歩行　HR



N=11-21, mean±SE, **: p<0.01, t検定(対応あり・片側)

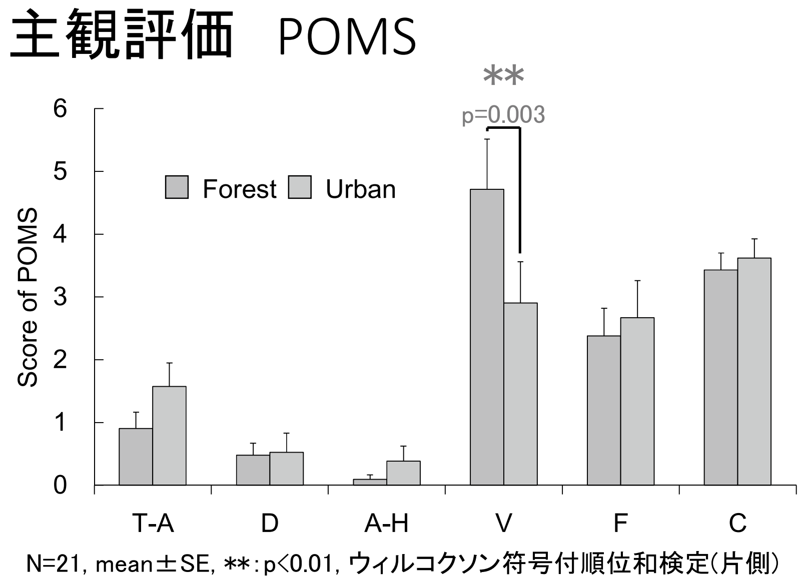
以下に午前 17 分間の森林歩行後の簡易 SD 法（「快適感」「鎮静間」「自然感」）を示す。森林浴によって、快適で、鎮静的で、自然であると感じられていることが明らかとなった。

主観評価　簡易SD法



N=21, mean±SE, **: p<0.01, ウィルコクソン符号付順位和検定(片側)

以下に午前17分間の森林歩行後の感情プロフィール検査（POMS）の結果を示す。森林浴によって、「活気」が有意に高まることが明らかとなった。



以上より、森林部午前歩行（17分間）は、都市部歩行に比べ、
1）生理的には
　①副交感神経活動（心拍変動性）を高めること
　②心拍数を減少させること
2）心理的には
　①「快適感」「鎮静感」「自然感」を高めること
　②POMSの「活気感」を高めること
が明らかとなった。

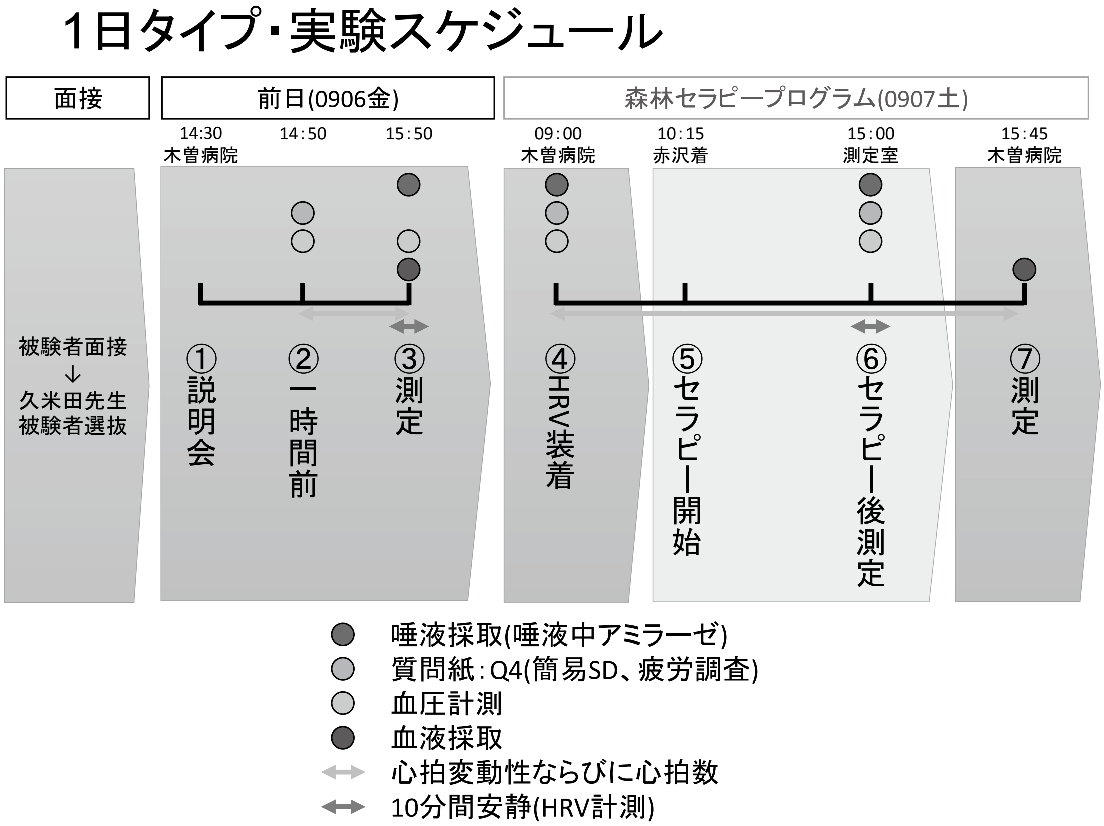
結論として、森林部歩行は生理的・心理的にリラックス状態をもたらすとともに主観的活気感を高めることが分かった。

Ⅱ 森林浴 1 日タイプ実験

（1）方法

1）実験デザイン

以下に森林浴1日タイプの実験デザインの概略を示す。



Ⅱ 森林浴 1 日タイプ実験

（1）方法

2）被験者情報

長野県立木曽病院に通院中の高血圧・未病状態の方々とし、被験者は中高年・高齢男性20名とした。

木曽病院実験1日タイプ　被験者情報

・・・血圧、アミラーゼ、HRVについて、血圧群別の分析

	年齢(歳)	身長(cm)	体重(kg)
mean	56.9	167.8	67.6
SD	12.7	7.6	11.8

被験者No	年齢	身長(cm)	体重(kg)	POMS実施	血圧別
1	40	168	88	○	<140
2	41	182	83	○	>=140
3	42	170	62	○	<140
4	42	166	76	○	<140
5	44	180	66	○	<140
6	–	–	–	○	–
7	47	171	76.5	○	<140
8	48	164	63	○	>=140
9	48	171	72	○	>=140
10	53	171	76	○	>=140
11	54	166	67	○	>=140
12	63	162.5	58.5	○	<140
13	64	177	83	○	<140
14	65	169.5	74	○	<140
15	69	154	62	○	<140
16	70	167.5	57	○	>=140
17	72	–	–	×	>=140
18	72	159.5	53.5	×	<140
19	73	154	43	×	>=140
20	74	168	57	×	>=140

血圧群	
高血圧群	正常高値血圧以下群
9	10

※血圧群

…セラピー日の朝(「セラピー前」):

収縮期血圧の平均値が140mmg以上

の被験者を、「高血圧群」とする。

Ⅱ 森林浴 1 日タイプ実験

（1）方法

3）測定手法

測定手法は森林浴 2 日タイプ実験と同様とした。

解説①

解説②

解説③

歩行①

歩行②

座って景色を眺める

体操

仰臥位

Ⅱ 森林浴１日タイプ実験

（2）結果と考察

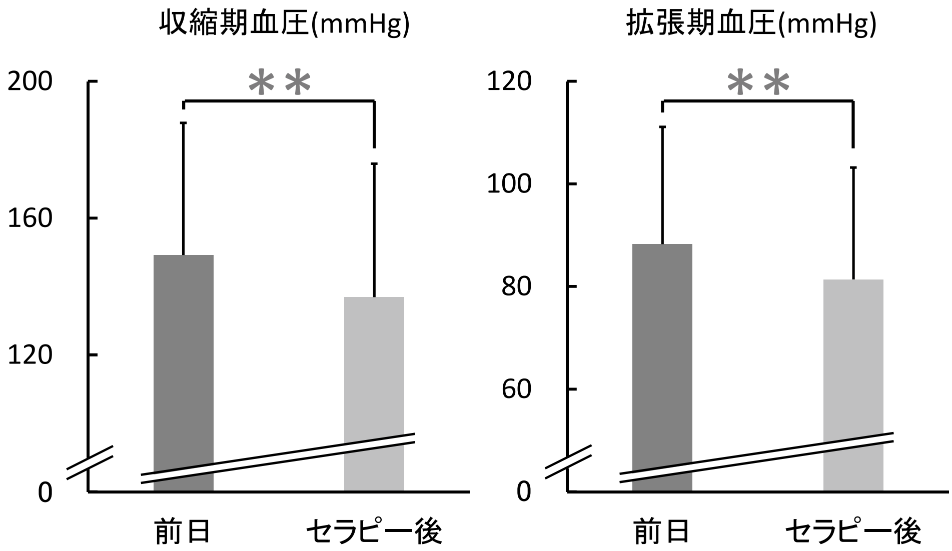
1）森林セラピープログラム実験

1. 全体

下記に収縮期血圧ならびに拡張期血圧の結果を示す。

森林セラピープログラム実施後、前日の同時刻における測定結果に比べ、有意に低下することが分かった。

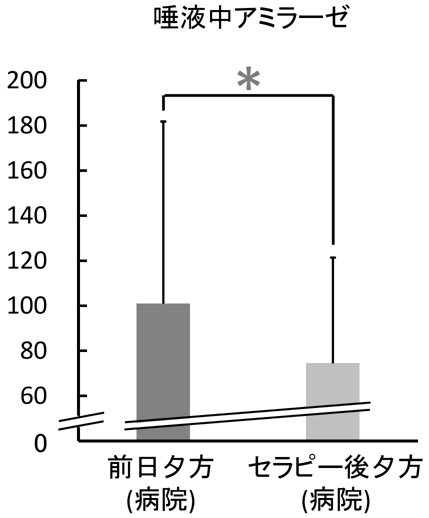
血圧の結果



N=19, mean±SD,), **: p<0.01, t検定(対応あり・片側

以下に唾液中アミラーゼ活性の結果を示す。血圧同様、前日の対照に比べ、有意に低下することが認められた。

唾液中アミラーゼの結果

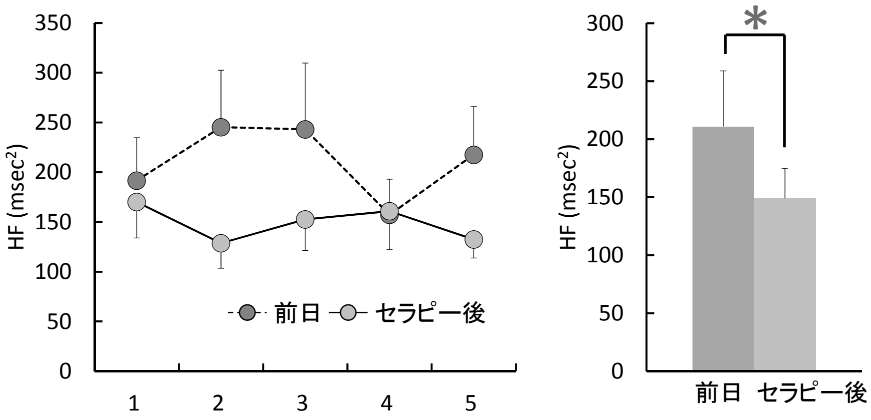


N=19, mean±SD, *: p<0.05, t検定(対応あり・片側)

以下に心拍変動性における副交感神経活動の結果を示す。

森林セラピープログラム後において、前日に比べ、有意に低下しており、仮説とは逆の結果を示した。

心拍変動性HFの結果



N=14, mean±SD, *: p<0.05, t検定(対応あり・片側)

以上より、自律神経活動における各種の指標間に一貫性がなく、本森林セラピープログラムが持つ効果については、不明であると結論付けられた。

以下に血液検査の結果を示す。

木曽病院実験1日タイプ
血液・尿成分　有意差一覧表

WBC	RBC	Hb	Hct	PLT	Neut%	Lymp%	Mono%	Eo%	Baso%
p=0.017 有意差あり (5%)	p=0.002 有意差あり (1%)	p=0.004 有意差あり (1%)	p=0.000 有意差あり (1%)	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし

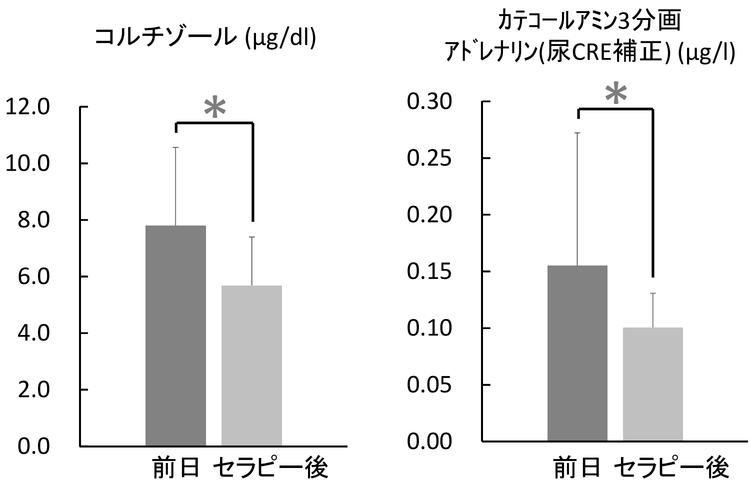
TG	TC	HDL	LDL	nonHDL	HbA1c	Glu	ｲﾝｽﾘﾝ	CRP	TSH
有意差なし	有意差なし	p=0.001 有意差あり (1%)	有意差なし	有意差なし	p=0.000 有意差あり (1%)	有意差なし	有意差なし	有意差なし	有意差なし

FT3	尿CRE	1.5AG	ﾘﾎﾟ蛋白ﾘﾊﾟｰｾﾞ	ｺﾙﾁｿﾞｰﾙ	DHEA-S	ｶﾃｺｰﾙｱﾐﾝ3分画(補正)			NTproBNP	ｱﾃﾞｨﾎﾟﾈｸﾁﾝ	RLPｺﾚｽﾃﾛｰﾙ
						ｱﾄﾞﾚﾅﾘﾝ	ﾉﾙｱﾄﾞﾚﾅﾘﾝ	ﾄﾞｰﾊﾟﾐﾝ			
有意差なし	有意差なし	有意差なし	有意差なし	p=0.000 有意差あり (1%)	p=0.002 有意差あり (1%)	有意差なし	p=0.024 有意差あり (5%)	有意差なし	有意差なし	p=0.016 有意差あり (5%)（逆転）	有意差なし

N=19 (平均年齢±SD, 56.4 ± 7.5歳), t検定(対応あり・両側)

以下に血中コルチゾールならびに尿中アドレナリン（クレアチニン補正）の結果を示す。共に、森林セラピープログラム実施後、前日の同時刻における測定結果に比べ、有意に低下し、生体のストレス状態が抑制されていることが分かった。

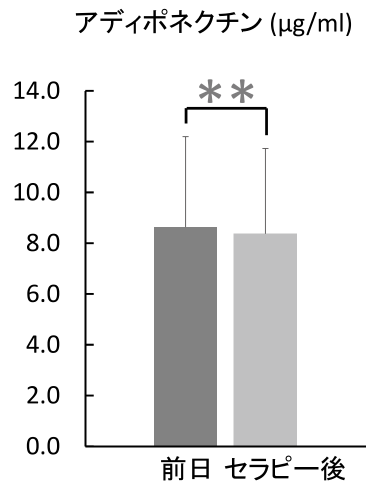
血液・尿成分の結果



N=19, mean±SD, *: p<0.05, t検定(対応あり・両側)

以下に血中アディポネクチンの結果を示す。仮説とは逆に森林セラピープログラム後に有意に低下したが、その理由は不明である。

血液・尿成分の結果



N=19, mean±SD, ** : p<0.01, t検定(対応あり・両側)

Ⅱ 森林浴１日タイプ実験

（2）結果と考察

1）森林セラピープログラム実験

2. 高血圧・正常高値血圧以下別評価

高血圧群と正常高値血圧以下群に分けて評価した各種指標の結果を以下に示す。

血圧別
(高血圧群、正常高値血圧以下群)

木曽病院実験1日タイプ
高血圧群ならびに境界域高血圧群における
HRV・血圧・脈拍数・アミラーゼ活性　有意差一覧表

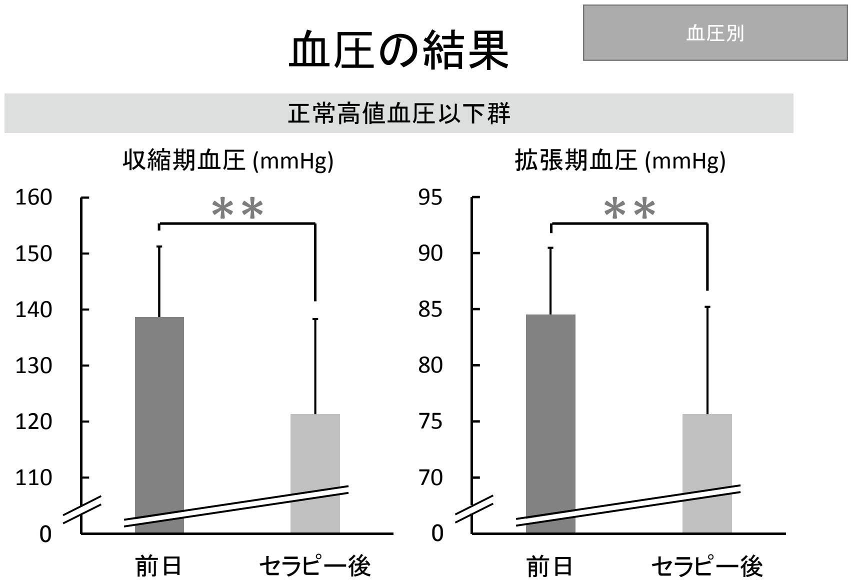
「セラピー前日(夕方)」-「セラピー当日(夕方)」の比較

※オレンジマーカー：全体結果では「有意差あり」

	HF (副交感神経活動)	LF/HF (交感神経活動)	HR (心拍数)	収縮期血圧	拡張期血圧	脈拍数	アミラーゼ活性
高血圧群	有意差なし	有意差なし	有意差なし	有意差なし	p=0.044 有意差あり (5%)	有意差なし	有意差なし
正常高値血圧以下群	有意差なし	有意差なし	有意差なし	p=0.0003 有意差あり (1%)	p=0.012 有意差あり (5%)	有意差なし	有意差なし

高血圧群 N=9, 正常高値血圧以下群 N=10, t検定(対応あり・片側)

以下に正常高値血圧以下群の結果を示す。収縮期血圧ならびに拡張期血圧ともに森林セラピープログラムによって有意に低下することが明らかとなった。



正常高値血圧以下群　N=10, mean±SD, **: p<0.01, t検定(対応あり・片側)

高血圧群と正常高値血圧以下群に分けて評価血液ならびに尿関連指標の結果を以下に示す。

血圧別
(高血圧群、正常高値血圧以下群)

血液・尿成分　有意差一覧表

※黄色マーカー: 全体結果では「有意差なし」
※オレンジマーカー: 全体結果では「有意差あり」

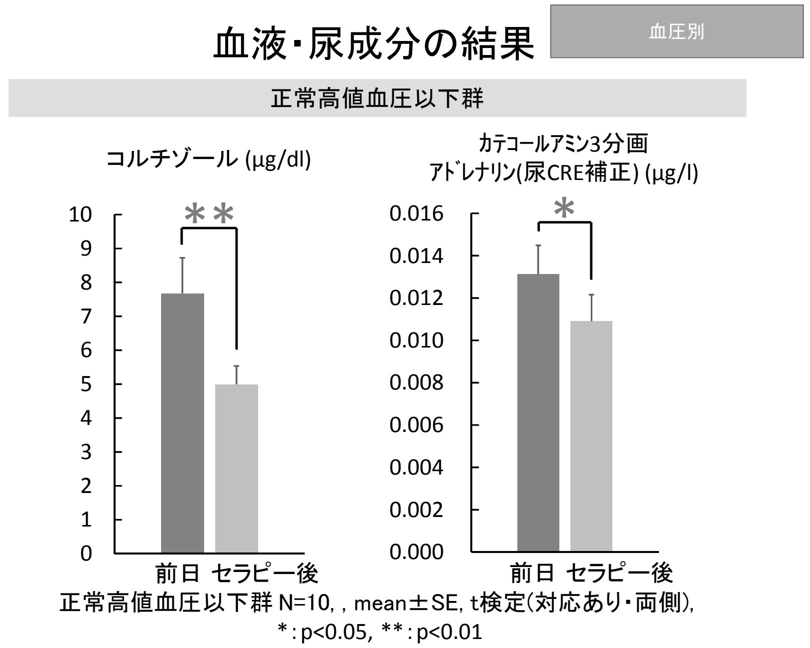
	WBC	RBC	Hb	Hct	PLT	Neut%	Lymp%	Mono%	Eo%	Baso%
高血圧群	有意差なし	有意差なし	有意差なし	p=0.022 有意差あり (5%)	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし
正常高値血圧以下群	p=0.000 有意差あり (1%)	p=0.023 有意差あり (5%)	p=0.043 有意差あり (5%)	p=0.007 有意差あり (1%)	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし

	TG	TC	HDL	LDL	nonHDL	HbA1c	Glu	ｲﾝｽﾘﾝ	CRP	TSH
高血圧群	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	p=0.000 有意差あり (1%)	有意差なし	有意差なし	有意差なし	有意差なし
正常高値血圧以下群	有意差なし	有意差なし	p=0.004 有意差あり (1%)	有意差なし	有意差なし	p=0.004 有意差あり (1%)	有意差なし	有意差なし	p=0.039 有意差あり (5%)	有意差なし

	FT3	尿CRE	1.5AG	ﾘﾎﾟ蛋白ﾘﾊﾟｰｾﾞ	ｺﾙﾁｿﾞｰﾙ	DHEA-S	ｶﾃｺｰﾙｱﾐﾝ3分画(補正)			NTproBNP	ｱﾃﾞｨﾎﾟﾈｸﾁﾝ	RLPｺﾚｽﾃﾛｰﾙ
							ｱﾄﾞﾚﾅﾘﾝ	ﾉﾙｱﾄﾞﾚﾅﾘﾝ	ﾄﾞｰﾊﾟﾐﾝ			
高血圧群	有意差なし	有意差なし	p=0.013 有意差あり (5%)	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし	有意差なし
正常高値血圧以下群	有意差なし	有意差なし	有意差なし	有意差なし	p=0.002 有意差あり (1%)	p=0.011 有意差あり (5%)	p=0.023 有意差あり (5%)	有意差なし	有意差なし	有意差なし	p=0.021 有意差あり (5%)（逆転）	有意差なし

高血圧群 N=9,正常高値血圧以下群 N=10, t検定(対応あり・両側)

以下に正常高値血圧以下群における血中コルチゾール濃度ならびに尿中アドレナリン濃度（クレアチニン補正）の結果を示す。仮説通りに両指標とも有意に低下していることが分かった。



結論として、

1）正常高値血圧以下群では、血圧の低下、血中コルチゾール濃度ならびに尿中アドレナリン濃度の低下が認められた。

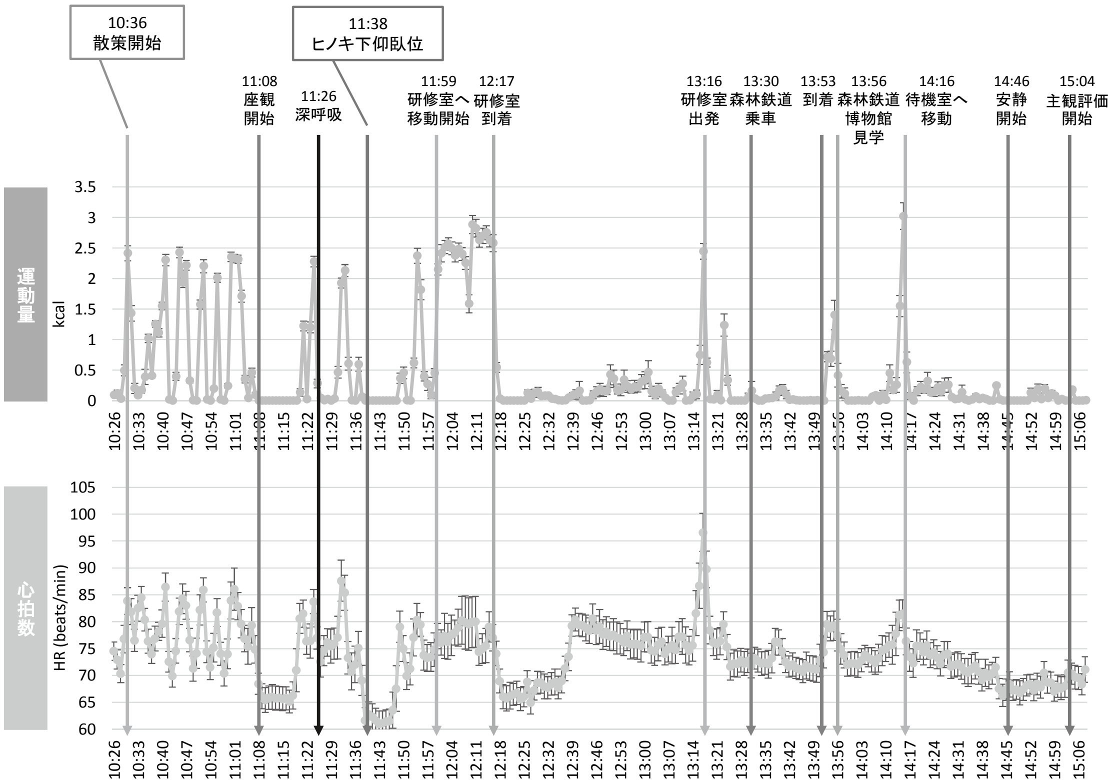
2）しかし、高血圧群全体では、各指標の変化に関して整合性が認められなかった。その理由として、高血圧群に対しては、森林セラピープログラムにおける運動量が過多であった可能性があると考えている。それによって、副交感神経活動の低下が生じたと思われる。

Ⅱ 森林浴１日タイプ実験

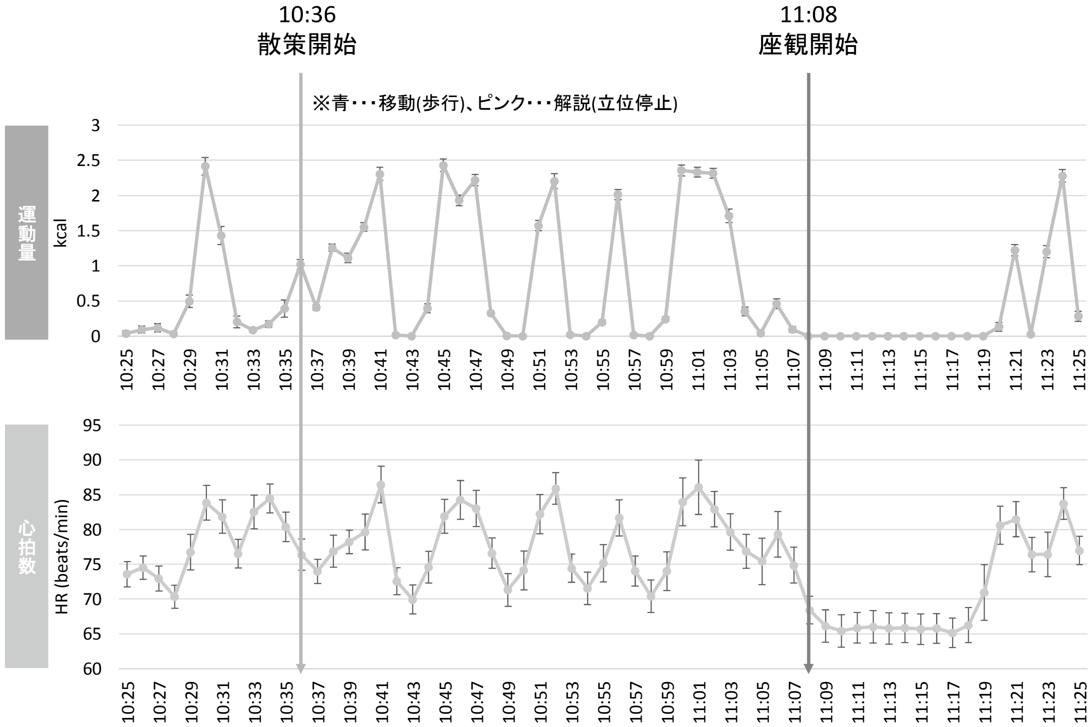
（2）結果と考察

2）森林セラピー時運動量と生理指標の関係

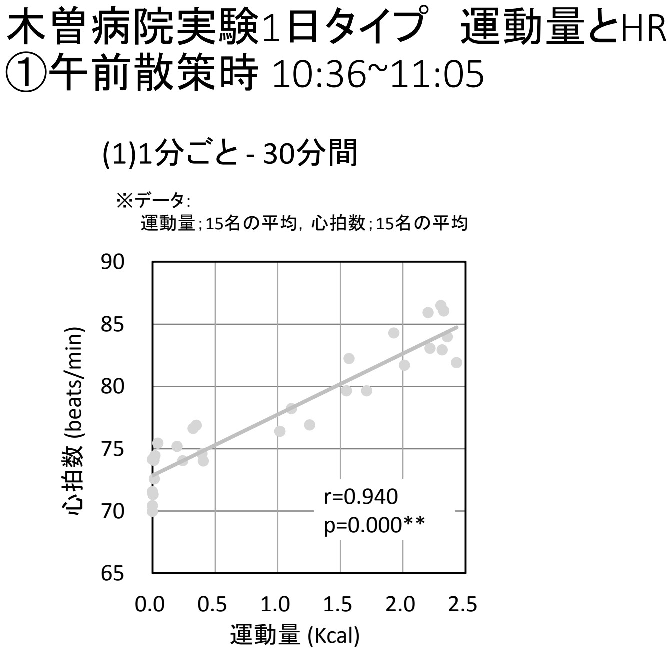
10 時 36 分から 15 時 6 分までの運動量と心拍数の経時的変化を示す。



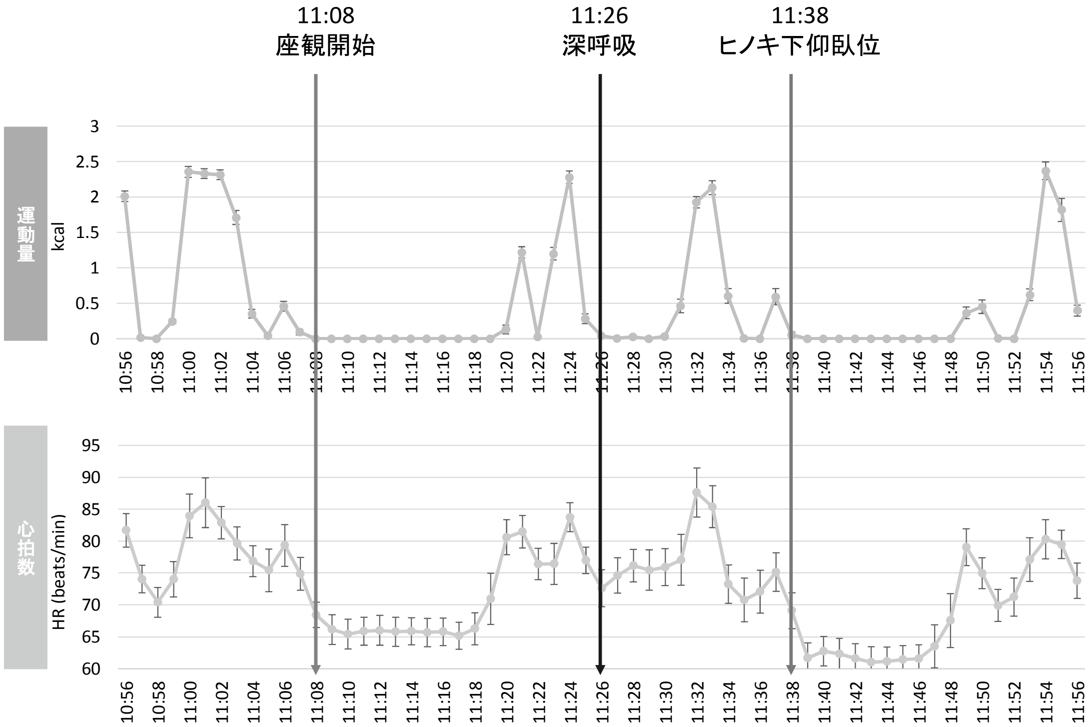
以下に、10 時 36 分から 11 時 25 分までの運動量と心拍数の経時的変化を示す。



以下に、10 時 36 分から 11 時 5 分までの運動量と心拍数の相関関係を以下に記す。
運動量と心拍数に高い相関があることが明らかとなった。



以下に、10 時 56 分から 11 時 56 分までの運動量と心拍数の経時的変化を示す。

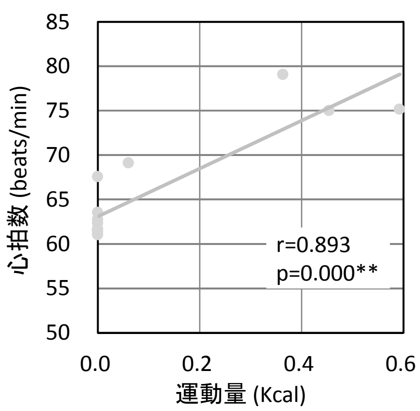


11 時 37 分から 11 時 50 分までの運動量と心拍数の相関関係を以下に記す。
運動量と心拍数に高い相関があることが明らかとなった。

木曽病院実験1日タイプ　運動量とHR
②ヒノキ下仰臥位 11:37~11:50

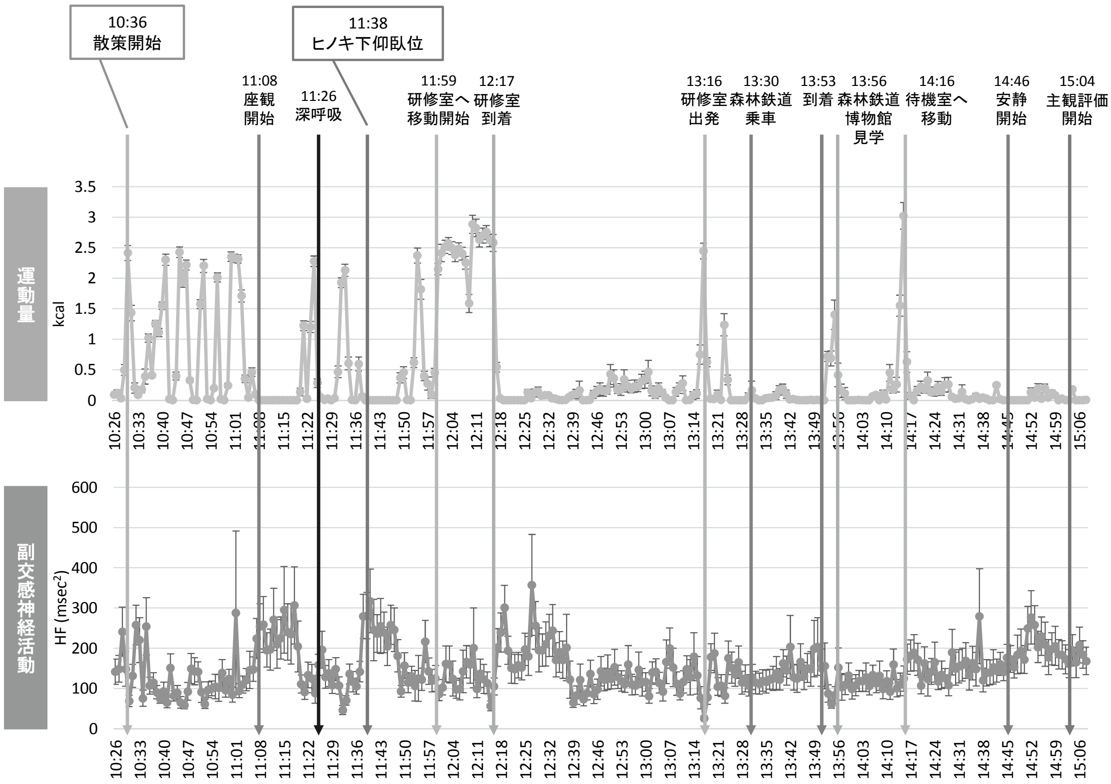
(1)1分ごと - 13分間

※データ:
運動量；15名の平均, 心拍数；15名の平均

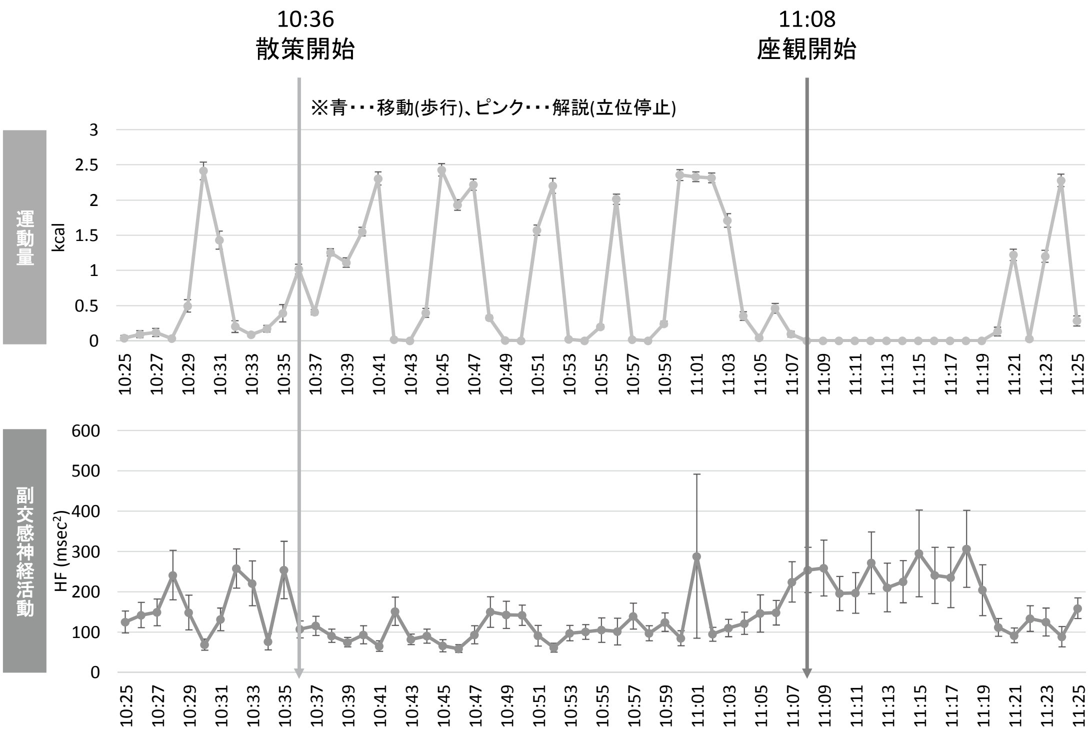


N=15, ピアソンの積率相関分析(両側)

以下に、10 時 26 分から 15 時 6 分までの運動量と副交感神経活動の経時的変化を示す。

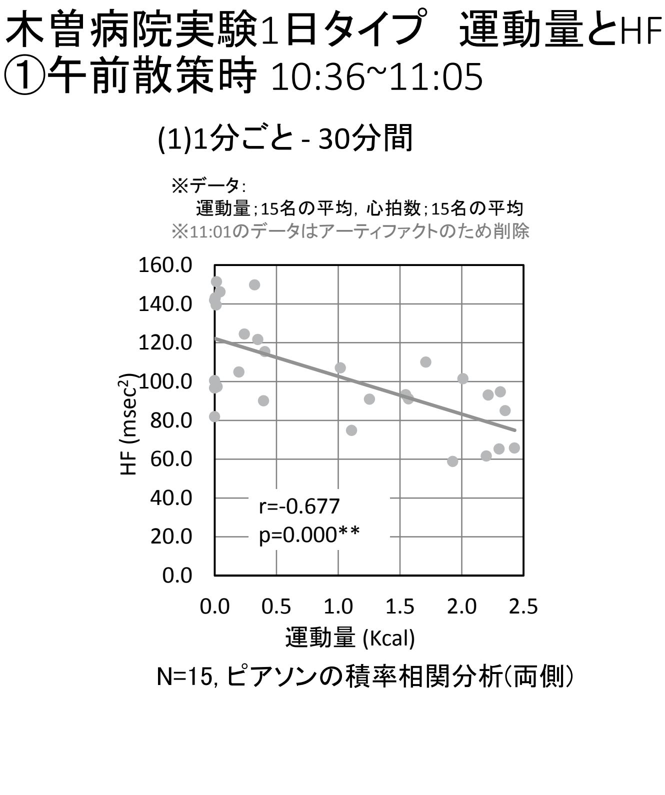


以下に、10 時 25 分から 11 時 25 分までの運動量と副交感神経活動の経時的変化を示す。

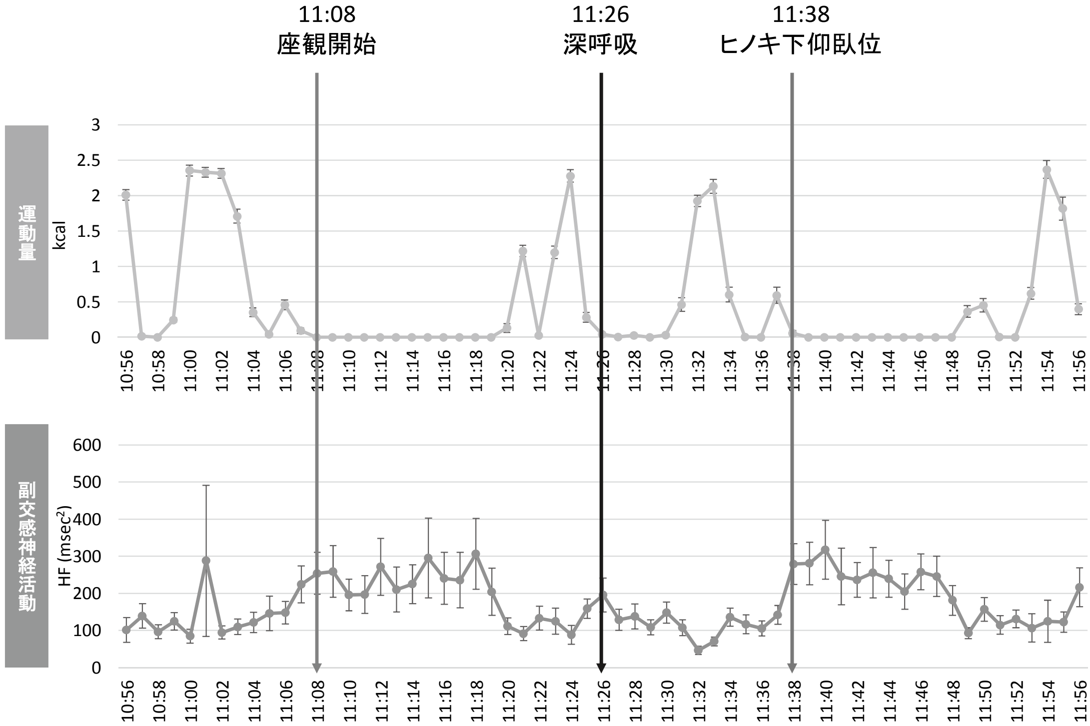


以下に、10 時 36 分から 11 時 5 分までの運動量と副交感神経活動の相関関係を以下に記す。

運動量と副交感神経活動に高い負の相関があることが明らかとなった。



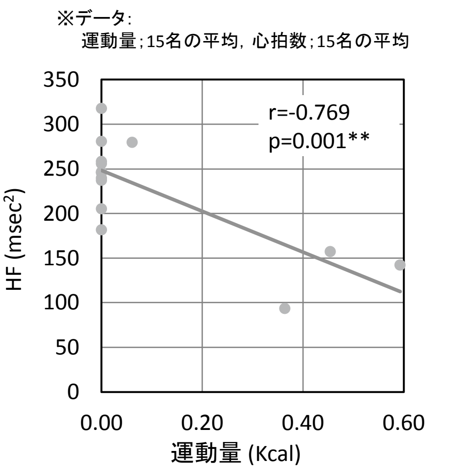
10 時 56 分から 11 時 56 分までの運動量と副交感神経活動の経時的変化を示す。



11 時 37 分から 11 時 5０分までの運動量と副交感神経活動の相関関係を以下に記す。運動量と副交感神経活動に高い負の相関があることが明らかとなった。

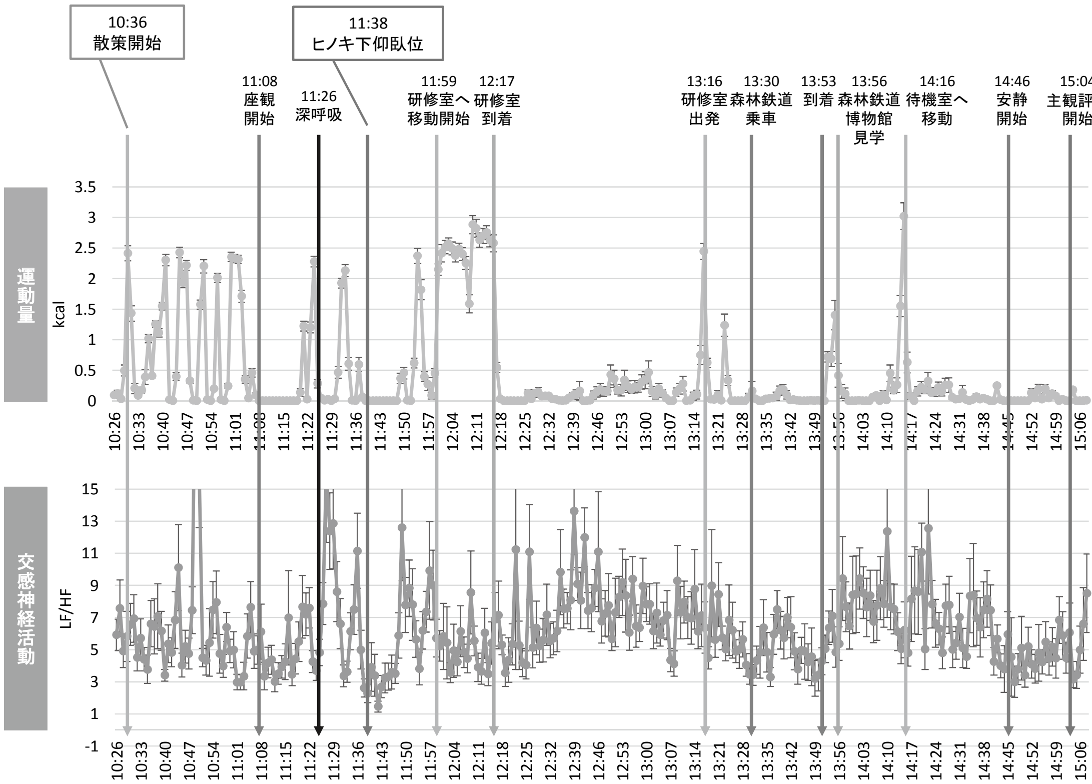
木曽病院実験1日タイプ　運動量とHF
②ヒノキ下仰臥位 11:37~11:50

(1)1分ごと - 13分間

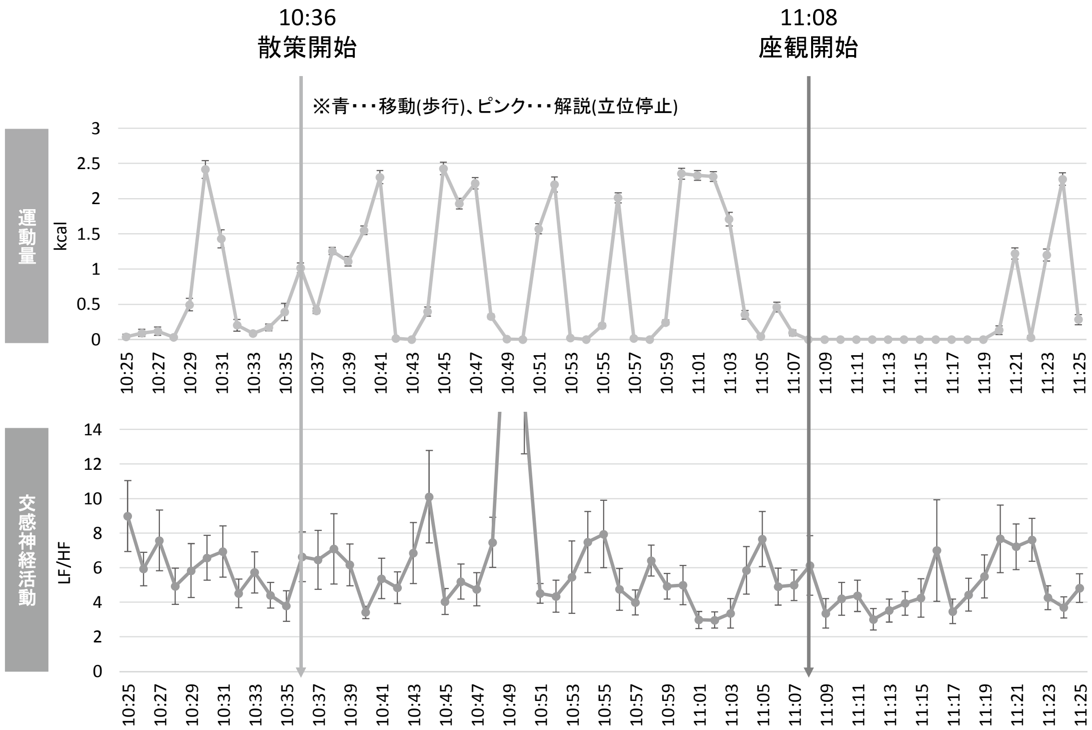


N=15, ピアソンの積率相関分析(両側)

以下に、10 時 25 分から 15 時 6 分までの運動量と交感神経活動の経時的変化を示す。

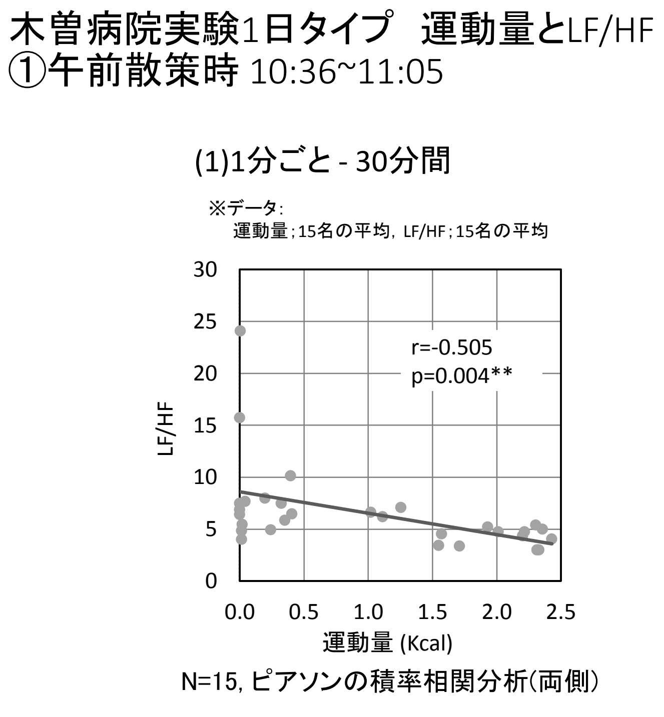


以下に、10 時 25 分から 11 時 25 分までの運動量と交感神経活動の経時的変化を示す。

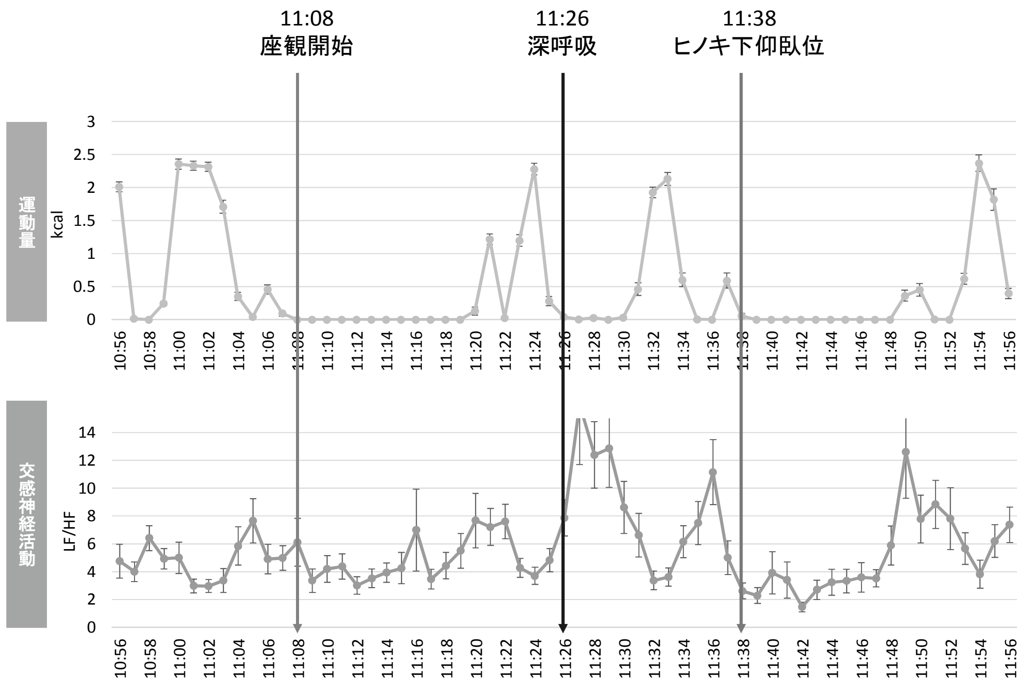


以下に、10 時 36 分から 11 時 5 分までの運動量と交感神経活動の経時的変化を示す。

下記の結果は仮説と逆である。運動に対して、交感神経活動がタイムラグを持っているのかも知れないが、その、理由については現状不明である。

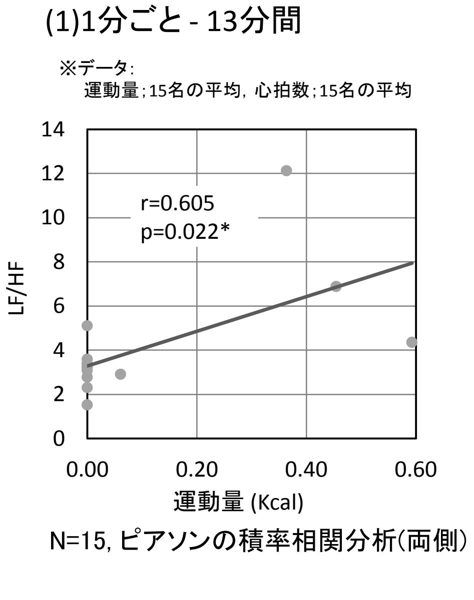


以下に、10 時 56 分から 11 時 56 分までの運動量と交感神経活動の経時的変化を示す。



以下に、11 時 37 分から 11 時 05 分までの運動量と交感神経活動の経時的変化を示す。本分析においては、仮説通りの相関を示した。

木曽病院実験1日タイプ　運動量とLF/HF
②ヒノキ下仰臥位 11:37~11:50



おわりに

平成 25 年度実験の成果は以下の通りである。

（1）森林浴 2 日タイプ実験においては、

1）高血圧男性被験者における森林歩行は生理的ならびに主観的リラックス効果をもたらすことが明かとなった。

本成果は、以下の論文としてインパクトファクター2. 1 の以下の雑誌に掲載された。

＝＝＝

Effect of forest walking on autonomic nervous system activity in middle-aged hypertensive individuals: a pilot study.

C. Song, H. Ikei, M. Kobayashi, T. Miura, M. Taue, T. Kagawa, Q. Li, S. Kumeda, M. Imai and Y. Miyazaki

International Journal of Environmental Research and Public Health 12(3): 2687-2699 2015

＝＝＝

2）高血圧男性被験者における森林内座観は生理的ならびに主観的リラックス効果をもたらすことが明かとなった。

Scandinavian Journal of Forest Research(IF:1.5)に投稿中である。

（2）森林浴 1 日タイプ実験においては、

1）正常高値血圧男性被験者における 1 日森林セラピープログラムは生理的ならびに主観的リラックス効果をもたらすことが明かとなった。

本成果も、以下の雑誌に掲載された。

＝＝＝

Physiological and psychological effects of forest therapy on middle-aged males with high-normal blood pressure

H. Ochiai, H. Ikei, C. Song, M. Kobayashi, A. Takamatsu, T. Miura, T. Kagawa, Q. Li, S. Kumeda, M. Imai and Y. Miyazaki

International Journal of Environmental Research and Public Health 12(3): 2532-2542 2015

＝＝＝

本研究は以下のメーバーの協力の元に実施された（五十音順）。

池井晴美（国立研究開発法人森林総合研究所）

今井通子（医師、国際自然・森林医学会長）

落合博子（国立病院機構東京医療センター）

香川隆英（国立研究開発法人森林総合研究所）

久米田茂喜（長野県立木曽病院名誉院長）

小林麻衣子（日本医科大学）

宋チョロン（千葉大学環境健康フィールド科学センター）

田上正男（長野県上松町）

高松亜子（国立成育医療研究センター）

見浦崇（長野県上松町）

李卿（日本医科大学）

Int. J. Environ. Res. Public Health **2015**, *12*, 2687-2699; doi:10.3390/ijerph120302687

OPEN ACCESS

International Journal of
Environmental Research and Public Health
ISSN 1660-4601
www.mdpi.com/journal/ijerph

Article

Effect of Forest Walking on Autonomic Nervous System Activity in Middle-Aged Hypertensive Individuals: A Pilot Study

Chorong Song [1,†], Harumi Ikei [1,†], Maiko Kobayashi [2], Takashi Miura [3], Masao Taue [4], Takahide Kagawa [5], Qing Li [2], Shigeyoshi Kumeda [6], Michiko Imai [7] and Yoshifumi Miyazaki [1,*]

1 Center for Environment, Health and Field Sciences, Chiba University, Kashiwa, Chiba 277-0882, Japan; E-Mails: crsong1028@gmail.com (C.S.); ikei.harumi@gmail.com (H.I.)
2 Department of Hygiene and Public Health, Nippon Medical School, Bunkyo-Ku, Tokyo 113-8602, Japan; E-Mails: mk831111@nms.ac.jp (M.K.); qing-li@nms.ac.jp (Q.L.)
3 Agematsu Town Office Industry & Tourism Department, Kiso, Nagano 399-5601, Japan; E-Mail: syoukan@town.agematsu.nagano.jp
4 Agematsu Town Office, Kiso, Nagano 399-5603, Japan; E-Mail: taue@town.agematsu.nagano.jp
5 Forestry and Forest Products Research Institute, Tsukuba City, Ibaraki Prefecture 305-8687, Japan; E-Mail: kagawa@ffpri.affrc.go.jp
6 Nagano Prefectural Kiso Hospital, Nagano 397-8555, Japan; E-Mail: kumeda-shigeyoshi@pref-nagano-hosp.jp
7 Le Verseau Inc., Setagaya-ku, Tokyo 156-0051, Japan; E-Mail: leverseau@mvb.biglobe.ne.jp

† These authors contributed equally to this work.

* Author to whom correspondence should be addressed; E-Mail: ymiyazaki@faculty.chiba-u.jp; Tel.: +81-4-7137-8113; Fax: +81-4-7137-8008.

Academic Editor: Paul B. Tchounwou

Received: 20 November 2014 / Accepted: 16 February 2015 / Published: 2 March 2015

Abstract: There has been increasing attention on the therapeutic effects of the forest environment. However, evidence-based research that clarifies the physiological effects of the forest environment on hypertensive individuals is lacking. This study provides scientific evidence suggesting that a brief forest walk affects autonomic nervous system activity in middle-aged hypertensive individuals. Twenty participants (58.0 ± 10.6 years) were instructed to walk predetermined courses in forest and urban environments (as control). Course length (17-min walk), walking speed, and energy expenditure were equal between the forest and urban environments to clarify the effects of each environment. Heart rate variability (HRV) and heart rate were used to quantify physiological responses. The modified semantic differential method and Profile of Mood States were used to determine psychological responses. The natural logarithm of the high-frequency component of HRV was significantly higher and heart rate was significantly lower when participants walked in the forest than when they walked in the urban environment. The questionnaire results indicated that, compared with the urban environment, walking in the forest increased "comfortable", "relaxed", "natural" and "vigorous" feelings and decreased "tension-anxiety," "depression," "anxiety-hostility," "fatigue" and "confusion". A brief walk in the forest elicited physiological and psychological relaxation effects on middle-aged hypertensive individuals.

Keywords: forest therapy; urban environment; walking; hypertension; middle-aged individuals; preventive medicine; heart rate variability; heart rate; semantic differential method; profile of mood state

---

1. Introduction

During the seven-million-year history of humans [1], they have lived in natural environments; thus, they experienced a drastic change when they began living in urban environments. Rapid urbanization and artificialization have affected the environment by increasing traffic along with air and water pollution, while decreasing the amount of available agricultural land and open spaces [2]. These environmental changes, especially climate changes, threaten human health and quality of life (QOL) [2–5]. Furthermore, the rapid development of information technology has increased what Brod describes as "technostress" [6], a modern disease of adaptation caused by unhealthy coping mechanisms for dealing with new computer technologies. When combined, these factors can severely affect humans. Several studies have reported that urban environments are stressful [7–9] and are associated with increasing mortality rates [10].

In our stressful modern age, the relaxing effects of a natural environment are very important. As our interest in improving health and QOL has increased, more attention has been focused on the role of nature in promoting human health and well-being. In particular, a great deal of attention is focused on the therapeutic effects of the forest environment or "forest therapy." Forest therapy uses the medically proven effects of walking in a forest and observing the environment to promote feelings of relaxation and improve both physical and mental health.

Many studies have demonstrated that a forest environment can have positive physiological and psychological effects [11–27]. When compared with an urban environment, viewing forest scenery or walking in forests can decrease cerebral blood flow in the prefrontal cortex [11], reduce blood pressure [12–15] and pulse rate [12–14,16,17], increase parasympathetic nerve activity [12,14–19], suppress sympathetic nerve activity [12,14,15,17–19], and decrease salivary cortisol concentrations of stress hormones [11–13,15–17]. In addition, a previous study reported that visiting a forest enhanced natural killer cell activity and improved immune function [20], and these effects continued for up to

1 month [21,22]. With regard to the psychological effects, several questionnaire-based studies reported that people who are in a forest environment experience positive feelings, which they describe as "comfortable", "soothed" and "natural" [11–14,17], as well as an improved mood and cognitive functioning [15,17–19,23–27].

Forest therapy has recently attracted attention as a preventive or alternative therapy [28,29], and its effects have been studied in elderly individuals and patients with reversible diseases. Lee and Lee [30] demonstrated that walking in a forest for 1 h improves arterial stiffness and pulmonary function in elderly women. Otsuka *et al.* [31] clarified that forest walking decreased blood glucose levels in patients with non-insulin-dependent diabetes mellitus. Other findings have indicated that cognitive behavioral therapy conducted in a forest environment was more successful in achieving depression remission than psychotherapy conducted in a hospital [32].

Several studies have demonstrated positive effects in hypertensive individuals. Mao *et al.* [33] reported that a seven-day forest-bathing trip reduces blood pressure and decreases pathological indicators of cardiovascular disease. Sung *et al.* [34] demonstrated that a frequent and eight weeks' forest therapy program based on cognitive behavioral therapy can reduce salivary cortisol levels and improve QOL in hypertensive patients. However, to the best of our knowledge, there are no evidence-based research studies that have used indices of autonomic nerve system activity to clarify the acute response of exposure to a forest environment.

Therefore, the purpose of the present study was to clarify the acute response of forest walking on autonomic nerve activity. We used heart rate variability (HRV) [35,36] and heart rate to measure autonomic responses and then compared these responses among middle-aged hypertensive individuals who walked in a forest and an urban environment.

2. Materials and Methods

2.1. Participants

Twenty Japanese men (mean age, 58.0 ± 10.6 years; mean body mass index, 23.4 ± 3.3 kg/m^2) participated in the experiment. The participants' information and characteristics are shown in Table 1. Participants who were taking medication for chronic conditions such as diabetes, hyperlipidemia, and hypertension were excluded. Among these 20 participants, five had a high-normal blood pressure (systolic 130–139 mmHg or diastolic 85–89 mmHg) that was considered in the higher range of prehypertension. Of the remaining 15 participants, 10 had hypertension stage 1 (systolic 140–159 mmHg or diastolic 90–99 mmHg) and five had hypertension stage 2 (systolic 160–179 mmHg or diastolic 100–109 mmHg). Furthermore, for the classification, the values measured in the morning (8:30–8:45) of the first experimental day were used.

Before the experiment, the participants were fully informed about the study aims and procedures; and after receiving a description of the experiment, they signed an agreement to participate in the study. Consumption of alcohol and tobacco was prohibited and consumption of caffeine was controlled during the study period. All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committees of the Nagano Prefectural Kiso Hospital, Japan and of the Center for Environment, Health, and Field Sciences, Chiba University, Japan (Project identification code number: 5).

Table 1. Participant demographics.

Parameter	Value (Mean ± Standard deviation)
Total sample number	20
Sex	Male
Age (years)	58.0 ± 10.6
Height (cm)	167.9 ± 6.2
Weight (kg)	66.1 ± 10.6
BMI (kg/m^2)	23.4 ± 3.3
SBP (mmHg)	151.2 ± 17.9
DBP (mmHg)	90.7 ± 5.0

2.2. Experimental Sites

The field experiments were conducted in a coniferous forest that included many Japanese cypress trees (Akasawa Shizen Kyuyourin; Akasawa natural recreation forest) and was located in Agematsu town of Nagano Prefecture situated in central Japan (hereafter referred to as the forest area). An urban area in Ina City of Nagano Prefecture was selected as the control site (hereafter referred to as the urban area). The weather was sunny on the days of experiments. In the forest area, the average temperature was 21.4 ± 1.2 °C with an average humidity of 82.3 ± 4.8%, whereas in the urban area, the average temperature was 28.1 ± 1.1 °C with an average humidity of 61.9 ± 4.5%.

2.3. Physiological Indices

HRV and heart rate, which were used to quantify autonomic nervous system responses, were measured using a wearable electrocardiogram sensing system (myBeat; Union Tool, Co., Tokyo, Japan). Frequency spectra were generated using an HRV software tool (MemCalc/Win; GMS, Tokyo, Japan) [37]. For real-time HRV analysis by the maximum entropy method, interbeat (R-R) intervals were obtained continuously. In this study, two broad HRV spectral components were calculated: low frequency (LF; 0.04–0.15 Hz) and high frequency (HF; 0.15–0.40 Hz). The HF component is an estimate of parasympathetic nerve activity, whereas the LF/HF ratio is an estimate of sympathetic nerve activity [35,36]. To normalize HRV parameters across participants for the analysis, we transformed the values using the natural logarithm [38].

2.4. Psychological Indices

The participants answered two questionnaires to investigate psychological responses. The modified semantic differential (SD) method [39] used three pairs of adjectives on thirteen scales, including "comfortable to uncomfortable", "relaxed to awakening" and "natural to artificial". The Profile of Mood State (POMS) [40–42] scores were determined for the following six subscales:

"tension-anxiety", "depression", "anger-hostility", "fatigue", "confusion" and "vigor". We used a short version of the POMS that included 30 questions in order to decrease the participants' burden.

2.5. Experimental Design

We performed a within-subject experiment. The 20 participants were randomly assigned to two groups of 10 each that participated in the experiment over two consecutive days. On the first day, one group traveled to the forest area and the other traveled to the urban area by car (about 45 min). On the second day, the groups switched walking courses to eliminate an order effect.

The participants moved within their respective experimental site once they arrived. After resting for 10 min, the participants were instructed to walk a predetermined course. An experimenter guided the participants along the course; the duration of each walk was 17 min (Figure 1), and the two experimenters leading the courses walked at almost the same speed. The course duration and walking speed of both the experimenters were set to be the same for both the forest and urban areas. The walking course in the forest area was mostly flat, except for a small slope (3.25%) in the first 6 min of the course, whereas that of the urban area was flat. The participants walked the two courses at approximately the same time of day (10:30–11:10) to eliminate the influence of diurnal changes on physiological rhythms.

HRV and heart rate data were collected at 1-min intervals and then averaged over the entire 17-min course. We then compared these average values between sites. Energy expenditure for walking was also assessed (Lifecorder GS4; Suzuken Co., LTD., Chiba, Japan). The participants answered the two questionnaires after completing each course.

The forest area The urban area

Figure 1. Experimental sites.

2.6. Statistical Analyses

Physiological data of 19 participants were used for analysis because of errors in data collection for one participant. We used the paired t-test to compare the mean HRV and heart rate between the two walking sites. We used the Wilcoxon signed-rank test to analyze differences the psychological indices completed after walking in each environment. All statistical analyses were performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). In all comparisons, a p-value of <0.05 was considered statistically significant. One-sided tests were used for both comparisons because our hypothesis was that elderly hypertensive individuals would also be relaxed after walking in a forest.

3. Results

We confirmed there were no significant differences in the energy expenditure between the two environments (forest, 1.99 kcal/min; urban, 2.03 kcal/min, $p > 0.05$). However, the participants showed significant differences in their physiological and psychological responses for the 17-min walk in the forest and the urban areas.

Figure 2 shows the natural logarithm of HF component ln(HF), which is an estimate of parasympathetic nerve activity. In the 1-min segment analysis, most ln(HF) values were higher when participants walked in the forest than when they walked in the urban area, except during the first 4-min period (Figure 2A). The mean ln (HF) over the entire walking period was significantly higher in forest walking than in urban walking (forest, 3.9 ± 0.2 lnms^2; urban, 3.5 ± 0.2 lnms^2; $p < 0.05$, Figure 2B). In contrast, there was no significant difference between the two environments for the natural logarithm of LF/HF (ln(LF/HF)), an estimate of sympathetic nerve activity.

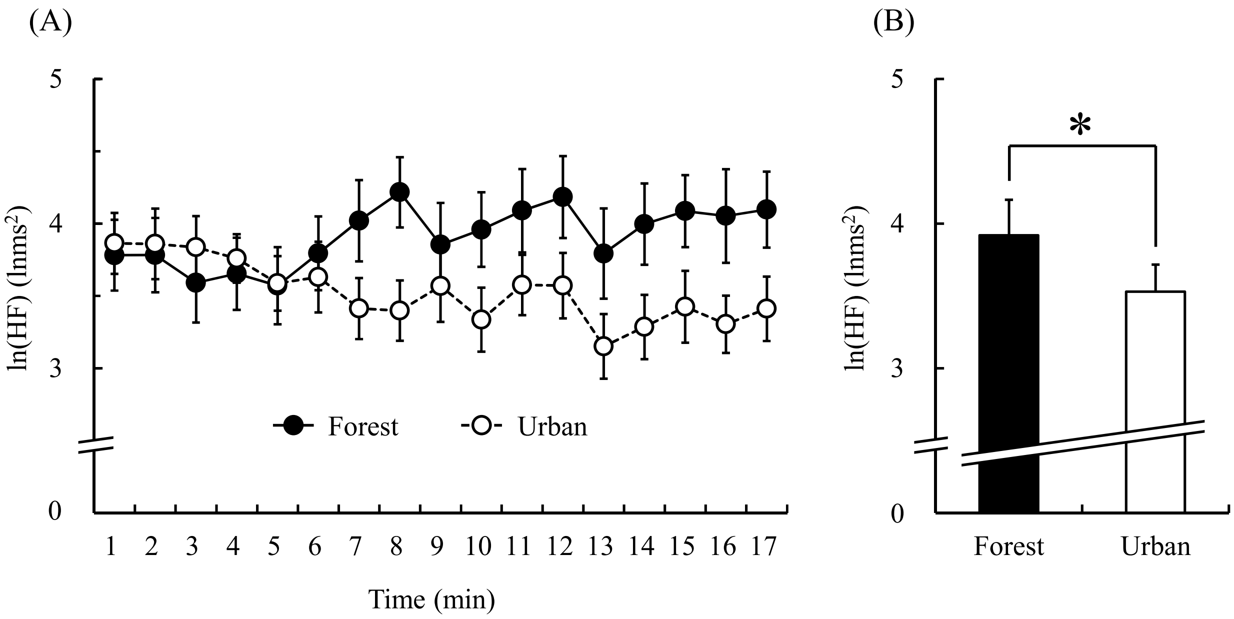


Figure 2. ln(HF) value of heart rate variability during the forest and urban walk. (**A**) Changes in each 1-min average ln(HF) value over the 17-min walk. (**B**) Overall mean ln(HF) values. $N = 19$, mean ± standard error. * $p < 0.05$, paired *t*-test.

Heart rate values were lower in forest walking than in urban walking, except during the first 6-min period (Figure 3A). The mean heart rate during the entire 17-min walk was significantly lower when participants walked in the forest area than when they walked in the urban area (forest, 77.1 ± 2.0 bpm; urban, 78.6 ± 1.8 bpm; $p < 0.05$, Figure 3B).

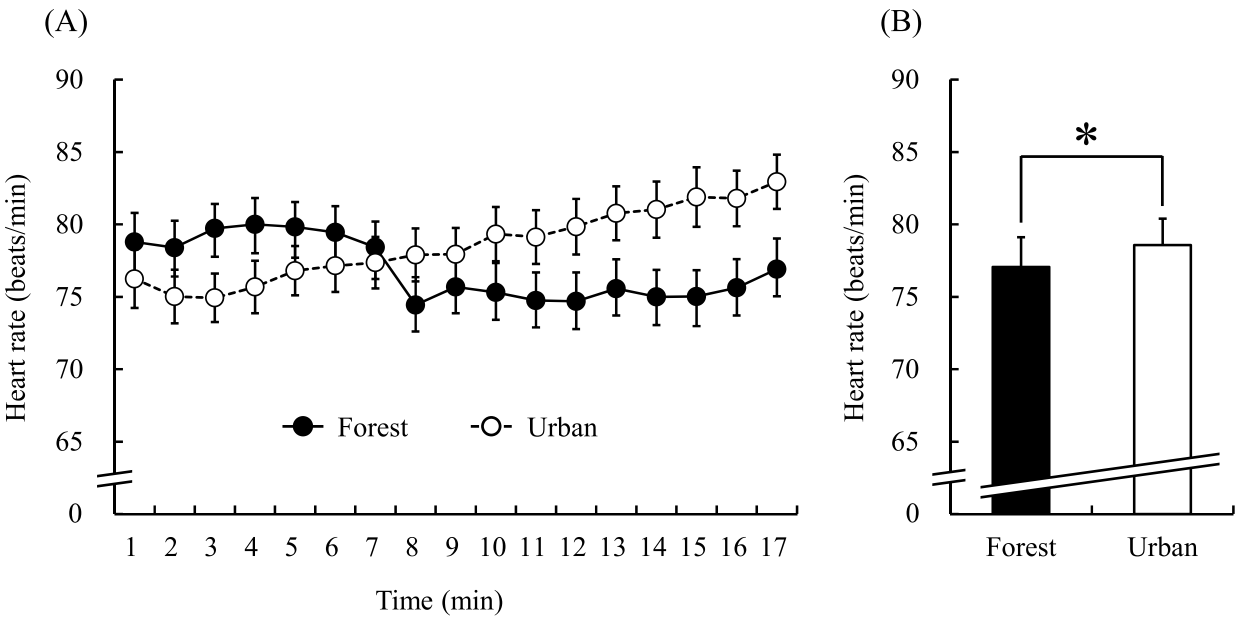


Figure 3. Heart rate during the forest and urban walk. (**A**) Changes in each 1-min heart rate value over the 17-min walk. (**B**) Overall mean heart rates. $N = 19$, mean ± standard error. * $p < 0.05$, paired t-test.

Our analysis of the participants' responses to the two questionnaires, the SD method and the POMS scores, revealed differences in psychological responses between the two environments. Participants felt more "comfortable", "relaxed" and "natural" when they walked in the forest area than in the urban area ($p < 0.01$, Figure 4). We also observed differences in the POMS test in which scores for the negative subscales of "tension–anxiety", "depression", "anger-hostility", "fatigue" and "confusion" were significantly lower after walking in the forest area than after walking in the urban area ($p < 0.05$, Figure 5). Conversely, the positive mood state "vigor" was significantly higher after walking in the forest area than after walking in the urban area ($p < 0.01$, Figure 5).

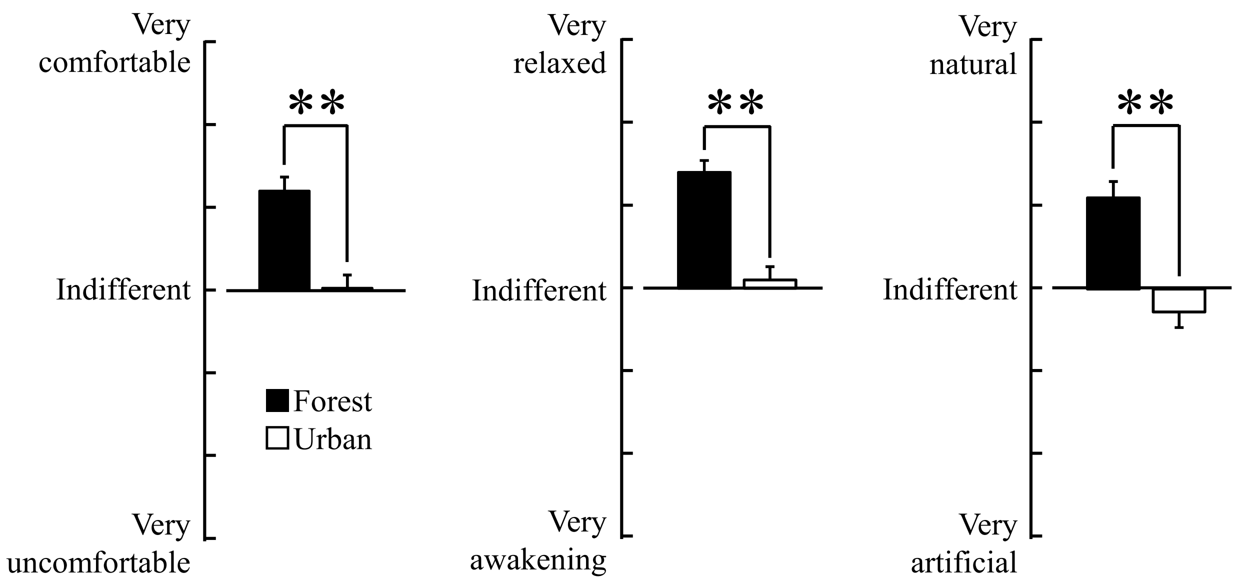


Figure 4. Comparison of "comfortable," "relaxed," and "natural" feeling scores between the two environments. $N = 20$, mean ± standard error. ** $p < 0.01$, Wilcoxon signed-rank test.

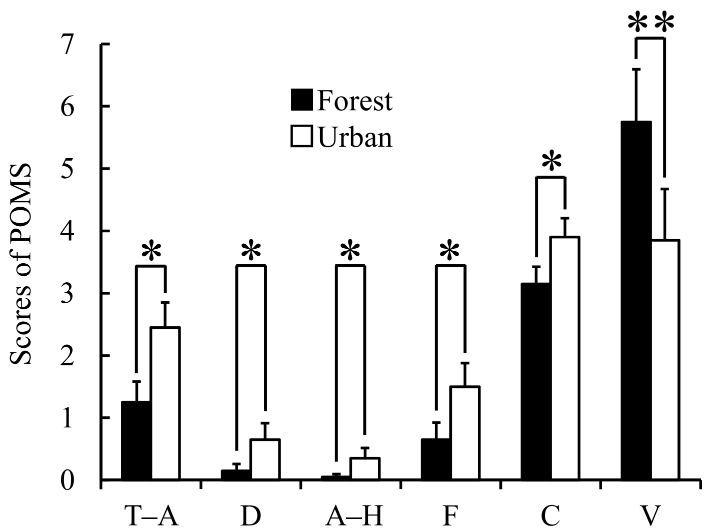


Figure 5. Comparison of Profile of Mood State (POMS) scores between the two environments. T–A: tension–anxiety; D: depression; A–H: anger–hostility; F: fatigue; C: confusion; V: vigor. $N = 20$, mean ± standard error. * $p < 0.05$, ** $p < 0.01$, Wilcoxon signed-rank test.

4. Discussion

A short walk in a forest can have significant physiological and psychological effects on middle-aged hypertensive individuals. Compared with walking in the urban environment, walking in the forest environment significantly increased parasympathetic nerve activity and significantly decreased heart rate. These results are consistent with those from previous studies that examined physiological responses to a forest environment in young adults [12,14–19]. HRV responses are often detected during relaxed states such as during rest [35], a massage [43,44], or after performing yoga [45]. Therefore, we concluded that participants who walked in the forest were in a physiologically relaxed state.

On the other hand, we observed the reverse in our analysis of ln(HF) and heart rate for the 1-min segments. We do not know the exact reason for this difference; however, because heart rate increases during walking and running, especially uphill [46–48], we suppose these physiological responses resulted from the small slope at the beginning of the forest area course. The slope was characterized by a forest environment. We believe that if this feature is used well, it will be of great merit to forest therapy programs.

In the questionnaires, the participants reported that they felt more "comfortable", "relaxed" and "natural" after walking in the forest. In addition, negative emotions such as "tension-anxiety," "depression", "anger-hostility", "fatigue" and "confusion" as well as the positive emotion of "vigor" improved significantly after walking in the forest. Our findings of the psychological benefits of walking in a forest are partly consistent with previous findings [11–15,18,23]. In the modern age, the importance of mental health has increased [49]. The psychological benefits of a forest environment may play a very important role in improving mental stress.

Furthermore, physical condition such as the average temperature (forest: 21.4 ± 1.2 °C, urban: 28.1 ± 1.1 °C) and humidity (forest: 82.3 ± 4.8%, urban: 61.9 ± 4.5%) was significantly different

($p < 0.01$ by unpaired t-test). Park *et al.* [23] examined the relationship between psychological responses to forest and urban areas and the physical variables of these environments. As a result, the psychological responses to physical environments were also significantly related to air temperature, relative humidity, radiant heat, wind velocity, PMV, and PPD. It is considered that different physical condition is one of the reasons for differences in physiological and psychological responses in the present results.

Walking is a simple, accessible, and cost-effective method to improve physical health, and this has been clarified in previous studies [50,51]. Iwane *et al*. [50] reported that walking at least 10,000 steps per day can lower blood pressure and suppress sympathetic nerve activity in hypertensive patients. Williams and Thompson [51] demonstrated that equivalent energy expenditures in walking and running could produce similar risk reductions for hypertension, hypercholesterolemia, and diabetes mellitus. However, it is not yet elucidated whether such effects can be attributed to differences in the walking environment.

The present findings suggest that these effects can differ with the environment. The present findings also clearly demonstrate that in middle-aged men, a brief walk in the forest was associated with relaxing physiological and psychological effects. However, this study had a few limitations. To generalize the findings, it is necessary to consider the following: First, these results cannot be extrapolated to the female population and people of different age groups. Further studies on a large sample including various subject groups are required. Second, the present study only used HRV and heart rate. For the overall discussion, future studies should be assessed to determine the effects of forest environment using other physiological indices, such as brain activity, autonomic nervous activity and endocrine activity.

5. Conclusions

Regarding the physiological and psychological effects of a brief walk in the forest environment for middle-aged individuals with hypertension, our study findings revealed the following: (1) a significant increase in parasympathetic nerve activity; (2) a significant decrease in heart rate; (3) a significant increase in "comfortable," "relaxed," and "natural" feelings assessed by the modified SD method combined with significant improvements in "tension-anxiety", "depression", "anger-hostility", "fatigue", "confusion" and "vigor" assessed by the POMS. In conclusion, walking in a forest induced physiological and psychological relaxation.

Acknowledgments

This study was conducted as a research project from the Vehicle Racing Commemorative Foundation.

Author Contributions

Chorong Song contributed to the experimental design, data acquisition, statistical analysis, interpretation of results, and manuscript preparation. Harumi Ikei contributed to the experimental design, data acquisition, statistical analysis, and interpretation of results. Maiko Kobayashi conducted data acquisition. Takashi Miura and Masao Taue contributed to preparing the experimental sites and

cooperated with data acquisition. Takahide Kagawa and Qing Li participated in data acquisition and contributed to the interpretation of results. Shigeyoshi Kumeda and Michiko Imai conceived the study and participated in the interpretation of results. Yoshifumi Miyazaki conceived and designed the study, contributed to the interpretation of results, and manuscript preparation. All authors have read and approved the final version submitted for publication.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Brunet, M.; Guy, F.; Pilbeam, D.; Mackaye, H.T.; Likius, A.; Ahounta, D.; Beauvilain, A.; Blondel, C.; Bocherens, H.; Boisserie, J.R.; *et al*. A new hominid from the Upper Miocene of Chad, Central Africa. *Nature* **2002**, *418*, 141–151.
2. Pronczuka, J.; Surdub, S. Children's environmental health in the twenty-first century. *N. Y. Acad. Sci.* **2008**, *1140*, 143–154.
3. Patz, J.A.; Campbell, L.D.; Holloway, T.; Foley, J.A.; Impact of regional climate change on human health. *Nature* **2005**, *438*, 310–317.
4. McMichael, A.J.; Woodruff, R.E.; Hales, S. Climate change and human health: present and future risks. *Lancet* **2006**, *367*, 859–869.
5. Kinney, P.L. Climate change, air quality, and human health. *Amer. J. Prev. Med.* **2008**, *35*, 459–467.
6. Craig, B. *Technostress: The Human Cost of the COMPUTER revolution*; Addison Wesley Press: Boston, MA, USA, 1984.
7. Ulrich, R.S.; Simons, R.F.; Losito, B.D.; Fiorito, E.; Miles, M.A.; Zelson, M. Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* **1991**, *11*, 201–230.
8. Lederbogen, F.; Kirsch, P.; Haddad, L.; Streit, F.; Tost, H.; Schuch, P.; Wüst, S.; Pruessner, J.C.; Rietschel, M.; Deuschle, M.; *et al*. City living and urban upbringing affect neural social stress processing in humans. *Nature* **2011**, *474*, 498–501.
9. Song, C.; Ikei, H.; Tsunetsugu, Y.; Lee, J.; Kagawa, T.; Miyazaki, Y.: Physiological and psychological impacts of walking stress in an urban environment on young males. *J. Geogr. Nat. Disast.* **2013**, *32*, doi:10.1186/1880-6805-32-18.
10. Tanaka, A.; Takano, T.; Nakamura, K.; Takeuchi, S. Health levels influenced by urban residential conditions in a megacity—Tokyo. *Urban Stud.* **1996**, *33*, 879–894.
11. Park, B.J.; Tsunetsugu, Y.; Kasetani, T.; Hirano, H.; Kagawa, T.; Sato, M.; Miyazaki, Y. Physiological effects of Shinrin-Yoku (taking in the atmosphere of the forest)—Using salivary cortisol and cerebral activity as indicators. *J. Physiol. Anthropol.* **2007**, *26*, 123–128.
12. Tsunetsugu, Y.; Park, B.J.; Ishi, H.; Hirano, H.; Kagawa, T.; Miyazaki, Y. Physiological effects of Shinrin-Yoku (taking in the atmosphere of the forest) in an oldgrowth broadleaf forest in Yamagata Prefecture, Japan. *J. Physiol. Anthropol.* **2007**, *26*, 135–142.

13. Lee, J.; Park, B.J.; Tsunetsugu, Y.; Kagawa, T.; Miyazaki, Y. Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. *Scand. J. Forest Res.* **2009**, *24*, 227–234.
14. Park, B.J.; Tsunetsugu, Y.; Kasetani, T.; Morikawa, T.; Kagawa, T.; Miyazaki, Y. Physiological effects of forest recreation in a young conifer forest in Hinokage Town, Japan. *Silva Fenn.* **2009**, *43*, 291–301.
15. Park, B.J.; Tsunetsugu, Y.; Kasetani, T.; Kagawa, T.; Miyazaki, Y. The physiological effects of Shinrinyoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environ. Health Prev. Med.* **2010**, *15*, 18–26.
16. Park, B.J.; Tsunetsugu, Y.; Ishi, H.; Furuhashi, S.; Hirano, H.; Kagawa, T.; Miyazaki, Y. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in a mixed forest in Shinano Town, Japan. *Scand. J. Forest Res.* **2008**, *23*, 278–283.
17. Lee, J.; Park, B.J.; Tsunetsugu, Y.; Ohira, T.; Kagawa, T.; Miyazaki, Y. Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. *Public Health* **2011**, *125*, 93–100.
18. Tsunetsugu, Y.; Lee, J.; Park, B.J.; Tyrvainen, L.; Kagawa, T.; Miyazaki, Y. Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurement. *Landsc. Urban Plan.* **2013**, *11*, 390–393.
19. Lee, J.; Tsunetsugu, Y.; Takayama, N.; Park, B.J.; Li, Q.; Song, C.; Komatsu, M.; Ikei, H.; Tyrväinen, L.; Kagawa, T.; *et al*. Influence of forest therapy on cardiovascular relaxation in young adults. *Evid. Based Compl. Altern. Med.* **2014**, *2014*, doi:10.1155/2014/834360.
20. Li, Q.; Morimoto, K.; Nakadai, A.; Inagaki, H.; Katsumata, M.; Shimizu, T.; Hirata, Y.; Hirata, K.; Suzuki, H.; Miyazaki, Y.; *et al*. Forest bathing enhances human natural killer activity and expression of anti-cancer proteins. *Int. J. Immunopathol. Pharmacol.* **2007**, *20*, 3–8.
21. Li, Q.; Morimoto, K.; Kobayashi, M.; Inagaki, H.; Katsumata, M.; Hirata, Y.; Hirata, K.; Suzuki, H.; Li, Y.J.; Wakayama, Y.; *et al*. Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. *Int. J. Immunopathol. Pharmacol.* **2008**, *21*, 117–127.
22. Li, Q.; Morimoto, K.; Kobayashi, M.; Inagaki, H.; Katsumata, M.; Hirata, Y.; Hirata, K.; Shimizu, T.; Li, Y.J.; Wakayama, Y.; *et al*. A forest bathing trip increases human natural killer activity and expression of anti-cancer proteins in female subjects. *J. Biol. Regulat. Homeost. Agent.* **2008**, *22*, 45–55.
23. Park, B.J.; Furuya, K.; Kasetani, T.; Takayama, N.; Kagawa, T.; Miyazaki, Y. Relationship between psychological responses and physical environments in forest settings. *Landsc. Urban Plan.* **2011**, *102*, 24–32.
24. Morita, E.; Fukuda, S.; Nagano, J.; Hamajima, N.; Yamamoto, H.; Iwai, Y.; Nakashima, T.; Ohira, H.; Shirakawa, T. Psychological effects of forest environments on healthy adults: Shinrin-Yoku (forest-air bathing, walking) as a possible method of stress reduction. *Public Health* **2007**, *121*, 54–63.
25. Shin, W.S.; Yeoun, P.S.; Yoo, R.W.; Shin, C.S. Forest experience and psychological health benefits: the state of the art and future prospect in Korea. *Environ. Health Prev. Med.* **2010**, *15*, 38–47.

26. Shin, W.S.; Shin, C.S.; Yeoun, P.S.; Kim, J.J. The influence of interaction with forest on cognitive function. *Scan. J. Forest Res.* **2011**, *26*, 595–598.
27. Mao, G.X.; Lan, X.G.; Cao, Y.B.; Chen, Z.M.; He, Z.H.; Lv, Y.D.; Wang, Y.Z.; Hu, X.L.; Wang, G.F.; Yan, J. Effects of short-term forest bathing on human health in a broad-leaved evergreen forest in Zhejiang province, China. *Biomed. Environ. Sci.* **2012**, *25*, 317–324.
28. Lee, J.; Li, Q.; Tyrväinen, L.; Tsunetsugu, Y.; Park, B.J.; Kagawa, T.; Miyazaki, Y. Nature therapy and preventive medicine. In *Public Health-Social and Behavioral Health*; Maddock, J.R., Ed.; InTech: Rijeka, Croatia, 2012; pp. 325–350.
29. Frumkin, H. Beyond toxicity: human health and the natural environment. *Amer. J. Prev. Med.* **2001**, *20*, 234–240.
30. Lee, J.Y.; Lee, D.C. Cardiac and pulmonary benefits of forest walking versus city walking in elderly women: A randomised, controlled, open-label trial. *Eur. J. Integr. Med.* **2014**, *6*, 5–11.
31. Ohtsuka, Y.; Yabunaka, N.; Takayama, S. Shinrin-Yoku (forest-air bathing and walking) effectively decreases blood glucose levels in diabetic patients. *Int. J. Biometeorol.* **1998**, *41*, 125–127.
32. Kim, W.; Lim, S.K.; Chung, E.J.; Woo, J.M. The effect of cognitive behavior therapy-based psychotherapy applied in a forest environment on physiological changes and remission of major depressive disorder. *Psychiat. Investig.* **2009**, *6*, 245–254.
33. Mao, G.X.; Cao, Y.B.; Lan, X.G.; He, Z.H.; Chen, Z.M.; Wang, Y.Z.; Hu, X.L.; Lv, Y.D.; Wang, G.F.; Yan, J. Therapeutic effect of forest bathing on human hypertension in the elderly. *J. Cardiol.* **2012**, *60*, 495–502.
34. Sung, J.; Woo, J.M.; Kim, W.; Lim, S.K.; Chung, E.J. The effect of cognitive behavior therapy-based "Forest Therapy" program on blood pressure, salivary cortisol level, and quality of life in elderly hypertensive patients. *Clin. Exp. Hypertens.* **2012**, *34*, 1–7.
35. Task force of the European society of cardiology and the north american society of pacing and electrophysiology: Heart rate variability: Standards of measurement, physiological interpretation and clinical use. *Circulation* **1996**, *93*, 1043–1065.
36. Pagani, M.; Lombardi, F.; Guzzetti, S.; Rimoldi, O.; Furlan, R.; Pizzinelli, P.; Sandrone, G.; Malfatto, G.; Dell'Orto, S.; Piccaluga, E. Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympatho-vagal interaction in man and conscious dog. *Circ. Res.* **1986**, *59*, 178–193.
37. Kanaya, N.; Hirata, N.; Kurosawa, S.; Nakayama, M.; Namiki, A. Differential effects of propofol and sevoflurane on heart rate variability. *Anesthesiology* **2003**, *98*, 34–40.
38. Kobayashi, H.; Park, B.J.; Miyazaki, Y. Normative references of heart rate variability and salivary alpha-amylase in a healthy young male population. *J. Physiol. Anthropol.* **2012**, *31*, doi:10.1186/1880-6805-31-9.
39. Osgood, C.E.; Suci, G.J.; Tannenbaum, P. *The Measurement of Meaning*; University of Illinois Press: Urbana, IL, USA, 1957.
40. McNair, D.; Lorr, M. An analysis of mood in neurotics. *J. Abnorm. Soc. Psych.* **1964**, *69*, 620–627.
41. McNair, D.; Lorr, M.; Droppleman, L. *Profile of Mood States Manual*; Educational and Industrial Testing Services: San Diego, CA, USA, 1992.
42. Yokoyama, K. *POMS Shortened Version-Manual and Commentary on Cases*; Kaneko Syoboh: Tokyo, Japan, 2005.

43. Delaney, J.P.; Leong, K.S.; Watkins, A.; Brodie, D. The short-term effects of myofascial trigger point massage therapy on cardiac autonomic tone in healthy subjects. *J. Adv. Nurs.* **2002**, *3*, 7364–7371.
44. Buttagat, V.; Eungpinichpong, W.; Chatchawan, U.; Kharmwan, S. The immediate effects of traditional Thai massage on heart rate variability and stress-related parameters in patients with back pain associated with myofascial trigger points. *J. Bodyw. Mov. Ther.* **2011**, *15*, 15–23.
45. Shapiro, D.; Cook, I.A.; Davydov, D.M.; Ottaviani, C.; Leuchter, A.F.; Abrams, M. Yoga as complementary of depression: Effects of traits and moods on treatment outcome. *Evid. Based Compl. Alternat. Med.* **2007**, *4*, 493–502.
46. Perrey, S.; Fabre, N. Exertion during uphill, level and downhill walking with and without hiking poles. *J. Sports Sci. Med*. **2008**, *7*, 32–38.
47. Minetti, A.E.; Moia, C.; Roi, G.S.; Susta, D.; Ferretti, G. Energy cost of walking and running at extreme uphill and downhill slopes. *J. Appl. Physiol.* **1985**, *93*, 1039–1046.
48. Padulo, J.; Annino, G.; Tihanyi, J.; Calcagno, G.; Vando, S.; Smith, L.; Vernillo, G.; La Torre, A.; D'ottavio, S. Uphill racewalking at iso-efficiency speed. *J. Strength Cond. Res.* **2013**, *27*, 1964–1973.
49. Murray, C.J.L.; Lopez, A.D. Evidence-based health policy—Lessons from the global burden of disease study. *Science* **1996**, *274*, 740–743.
50. Iwane, M.; Arita, M.; Tomimoto, S.; Satani, O.; Matsumoto, M.; Miyashita, K.; Nishio, I. Walking 10,000 steps/day or more reduces blood pressure and sympathetic nerve activity in mild essential hypertension. *Hypertens. Res.* **2000**, *23*, 573–580.
51. Williams, P.T.; Thompson, P.D. Walking versus running for hypertension, cholesterol, and diabetes mellitus risk reduction. *Arterioscler. Thromb. Vasc. Biol*. **2013**, *33*, 1085–1091.

Int. J. Environ. Res. Public Health **2015**, *12*, 2532-2542; doi:10.3390/ijerph120302532

OPEN ACCESS

International Journal of
Environmental Research and Public Health
ISSN 1660-4601
www.mdpi.com/journal/ijerph

Communication

Physiological and Psychological Effects of Forest Therapy on Middle-Aged Males with High-Normal Blood Pressure

Hiroko Ochiai [1,†], Harumi Ikei [2,†], Chorong Song [2,†], Maiko Kobayashi [3], Ako Takamatsu [4], Takashi Miura [5], Takahide Kagawa [6], Qing Li [3], Shigeyoshi Kumeda [7], Michiko Imai [8] and Yoshifumi Miyazaki [2,*]

[1] Department of Plastic and Reconstructive Surgery, National hospital organization Tokyo Medical Center, Higashigaoka 2-5-1, Meguro-ku, Tokyo 152-8902, Japan; E-Mail: ochiroko@gmail.com

[2] Center for Environment, Health and Field Sciences, Chiba University, Kashiwa-no-ha 6-2-1, Kashiwa, Chiba 277-0882, Japan; E-Mails: ikei.harumi@gmail.com (H.I.); crsong1028@gmail.com (C.S.)

[3] Department of Hygiene and Public Health, Nippon Medical School, Sendagi 1-1-5, Bunkyo-ku, Tokyo 113-8602, Japan; E-Mails: mk831111@nms.ac.jp (M.K.); qing-li@nms.ac.jp (Q.L.)

[4] Department of Plastic and Reconstructive Surgery, National Center for Child Health and Development, Okura 2-10-1, Setagaya-ku, Tokyo 157-8535, Japan; E-Mail: accodr@aol.com

[5] Agematsu Town Office Industry & Tourism Department, Agematsu 159-3, Kiso, Nagano 399-5601, Japan; E-Mail: syoukan@town.agematsu.nagano.jp

[6] Forestry and Forest Products Research Institute, 1 Matsunosato, Tsukuba City, Ibaraki Prefecture 305-8687, Japan; E-Mail: kagawa@ffpri.affrc.go.jp

[7] Nagano Prefectural Kiso Hospital, Kisomachi-fukushima 6613-4, Nagano 397-8555, Japan; E-Mail: kumeda@titan.ocn.ne.jp

[8] Le Verseau Inc., 3-19-4 Miyasaka, Setagaya-ku, Tokyo 156-0051, Japan; E-Mail: leverseau@mvb.biglobe.ne.jp

† These authors contributed equally to this work.

* Author to whom correspondence should be addressed; E-Mail: ymiyazaki@faculty.chiba-u.jp; Tel.: +81-4-7137-8113; Fax: +81-4-7137-8008.

Academic Editor: Paul B. Tchounwou

Received: 20 January 2015 / Accepted: 17 February 2015 / Published: 25 February 2015

Abstract: Time spent walking and relaxing in a forest environment ("forest bathing" or "forest therapy") has well demonstrated anti-stress effects in healthy adults, but benefits for ill or at-risk populations have not been reported. The present study assessed the physiological and psychological effects of forest therapy (relaxation and stress management activity in the forest) on middle-aged males with high-normal blood pressure. Blood pressure and several physiological and psychological indices of stress were measured the day before and approximately 2 h following forest therapy. Both pre- and post-treatment measures were conducted at the same time of day to avoid circadian influences. Systolic and diastolic blood pressure (BP), urinary adrenaline, and serum cortisol were all significantly lower than baseline following forest therapy ($p < 0.05$). Subjects reported feeling significantly more "relaxed" and "natural" according to the Semantic Differential (SD) method. Profile of Mood State (POMS) negative mood subscale scores for "tension-anxiety," "confusion," and "anger-hostility," as well as the Total Mood Disturbance (TMD) score were significantly lower following forest therapy. These results highlight that forest is a promising treatment strategy to reduce blood pressure into the optimal range and possibly prevent progression to clinical hypertension in middle-aged males with high-normal blood pressure.

Keywords: forest therapy; high-normal blood pressure; adrenaline; cortisol; preventive medicine; Semantic Differential method; Profile of Mood State

1. Introduction

While technology and modern city life offer unparalleled economic opportunities, conveniences, and comforts, urban environments are also stressful [1,2], which may contribute to chronic health problems. Many urban dwellers are thus looking for convenient methods of stress relief. Of these, the relaxing effects of natural environments are increasingly recognized as an effective counter to urban stress. The term "Shinrin-yoku" (taking in the atmosphere of the forest or literally "forest bathing") was coined by the Japanese Ministry of Agriculture, Forestry and Fisheries to describe the positive effects of brief sojourns in natural environments to improve general health [3]. In later years, the term "Shinrin-yoku" developed into "Forest Therapy," which uses the medically proven effects of walking and observing in a forest. Indeed, "Forest Therapy" is increasingly recognized as a relaxation and stress management activity with demonstrated clinical efficacy [4].

A variety of physiological indices show that humans are more relaxed in forested environments [3–8]. For example, a forest environment lowers blood pressure and pulse rate in humans [5–7]. Forest walking also suppresses sympathetic activity and increases parasympathetic activity [6,7] and reduces the levels of cortisol and cerebral blood flow in the prefrontal cortex [3]. It was also shown that a forest bathing trip can increase human natural killer (NK) cell activity and improve immunity in both males and females, and these effects were proved to last for at least 7 days [8]. In addition, psychological studies have demonstrated the benefits of forest environments on subjective measures of stress, cognitive function, and mood [5,6]. Park *et al.* reported the relaxation and stress management effects of forest environments by several questionnaire-based studies [9] as well as improved mood and cognitive function [10].

In psychological tests of young adult males, forest bathing significantly increased positive feeling scores and reduced negative feeling scores compared with urban stimuli [5,6,10].

However, previous studies have only investigated the physiological and psychological responses to forest bathing in healthy young adults, while such effects may be even more beneficial to middle-age subjects in the early stages of age-related diseases such as hypertension. Moreover, it is generally accepted that effects of treatment on blood pressure may vary between healthy normotensives and subjects with higher blood pressure, so studies on the latter population may be of greater clinical relevance. Therefore, the aim of this study was to measure the physiological and psychological effects of forest therapy on middle-aged males with high-normal blood pressure.

2. Materials and Methods

2.1. Participants

Nine Japanese males ranging in age from 40 to 72 years (56 ± 13.0; mean ± standard deviation) participated in this experiment. Potential participants who were taking medication for chronic conditions such as diabetes, hyperlipidemia, and hypertension were excluded. All participants had high-normal blood pressure (systolic 130–139 mmHg or diastolic 85–89 mmHg) as measured at Nagano Prefecture Kiso Hospital. Systolic blood pressure ranged from 124.5 to 137.5 mmHg (131.8 ± 4.1 mmHg) and diastolic blood pressure from 65.7 to 86.7 mmHg (77.3 ± 7.1 mmHg).

At the beginning of the experiment, subjects gathered in a waiting room at Nagano Prefecture Kiso Hospital and were fully informed about the study aims and procedures involved. After receiving a description of the experiment, the subjects all signed an agreement to participate. To control for the effect of alcohol, subjects did not consume alcohol during the entire study period. This study was approved by the Ethics Committee of Nagano Prefecture Kiso Hospital and the Center for Environment, Health and Field Sciences, Chiba University, Japan, on 19 August 2013 and performed according to the Declaration of Helsinki (1975, revised in 2008).

2.2. Experimental Sites

The forest therapy phase was conducted in Akasawa Shizen Kyuyourin (Akasawa Natural Recreation Forest), Agematsu, Nagano Prefecture (situated in central Japan) on 7 September 2013. Distance from the waiting room at Nagano Prefecture Kiso Hospital to the forest was 21.6 km, and it took 52 min to drive by car. The weather was cloudy, with a temperature of 21.5 °C (19.1 °C–25.0 °C) and humidity of 80.4% (62%–92%) on the day of forest therapy.

2.3. Physiological Indices

Systolic and diastolic blood pressure readings were obtained from the right arm using a portable digital sphygmomanometer (HEM-1020, Omron, Kyoto, Japan). Urine and blood samples were also obtained for the measurement of adrenaline, creatinine, and cortisol, respectively. All procedures were performed between 15:14 and 15:35 on the day before and a few hours after forest therapy to control for circadian effects. Participants were not allowed to talk each other during the measurement.

2.4. Psychological Indices

The Semantic Differential (SD) method, Profile of Mood State (POMS) subscale scores, and combined POMS Total Mood Disturbance (TMD) score were used to evaluate psychological responses to forest therapy. These questionnaires were completed by participants on the day before and soon after the experiment between 15:05 and 15:35. The SD method uses three pairs of adjectives anchoring seven-point scales: "comfortable to uncomfortable," "relaxed to awakening," and "natural to artificial" [11]. The POMS scores were determined for the following six subscales: "tension-anxiety (T-A)," "confusion (C)," "anger-hostility (A-H)," "depression (D)," "fatigue (F)," and "vigor (V)." A short form of the POMS with 30 questions was used to decrease the burden on the subjects [12]. The TMD score was calculated by combining T-A + C + A-H + D + F − V. A high TMD score indicates an unfavorable psychological state.

2.5. Experimental Design

Participants spent the previous night in their respective homes. In the morning of the forest therapy day, participants gathered in the same meeting room at 9:00 a.m. and participated in the forest therapy program as a group with a guide. They were not allowed to communicate with each other during forest therapy, except during lunch time and designated rest periods, and they were not permitted to carry cell phones. Participants walked around their assigned area and then sat and lay on their backs in the forest on waterproof sheets laid on the ground; this program, comprising multiple actions, was performed for 4 h and 35 min (Table 1, Figure 1).

Table 1. Time schedules of and calorie consumption during various activities of forest therapy.

Time	Event	Calorie Consumption (Kcal/min)
10:30–11:08	Stroll (Forest)	0.92
11:09–11:20	Sit (Forest)	0
11:21–11:26	Stroll (Forest)	0.85
11:27–11:31	Deep breathing (Forest)	0.02
11:32–11.39	Stroll (Forest)	0.71
11:40–11:49	Lie down (Forest)	0
11:50–12:17	Stroll (Forest)	1.72
12:18–13:16	Lunch and rest (Resting room)	0.12
13:17–13:30	Stroll (Forest)	0.38
13:31–13:53	Ride on the "Forest train" (Forest)	0.04
13:54–13:58	Stroll (Forest)	0.64
13:59–14:16	Stroll (Indoor pavilion)	0.31
14:17–14:32	Stroll (Forest)	0.17
14:33–15:05	Rest (Resting room)	0.05

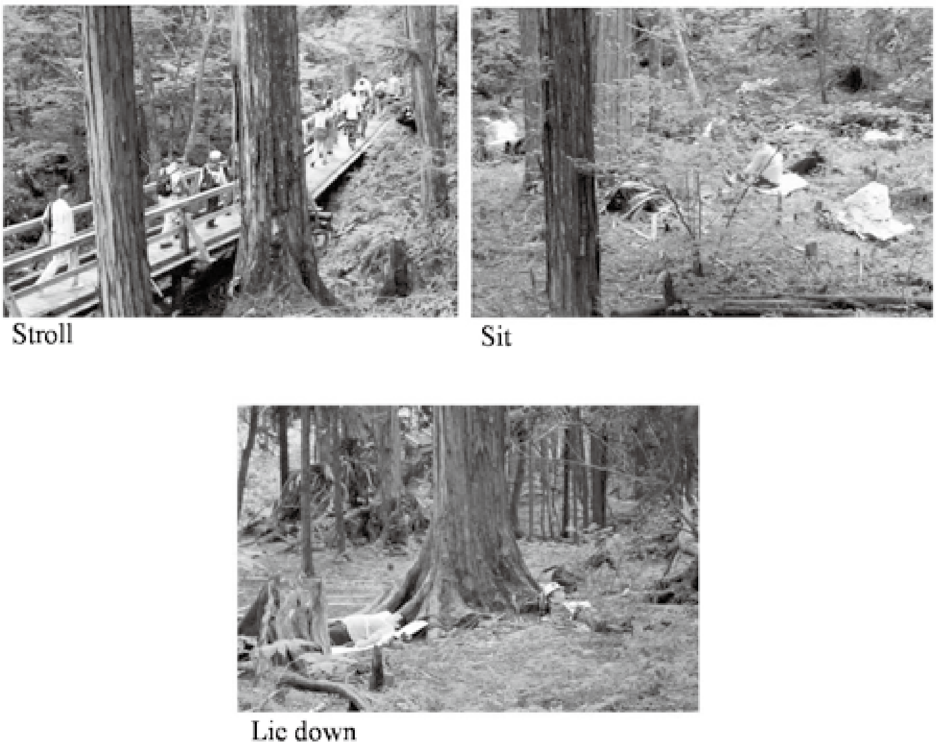


Figure 1. Images of the forest therapy experiment.

Energy expenditure for the activity was assessed (Lifecorder GS4; Suzuken Co., Ltd., Chiba, Japan). Tobacco and all drinks (except mineral water) were prohibited during forest therapy. They had the same lunch, which was made at lunch time from local ingredients. The subjects walked around their assigned areas and then sat and lay on their backs for 4 h and 45 min. Subjects then returned to a waiting room and completed the post-treatment measurements and questionnaires. These results were then compared with the data obtained on the day before.

2.6. Statistical Analysis

We used paired sample t-tests to compare physiological indices and the Wilcoxon signed-rank test to compare psychological test results before and after forest bathing. All statistical analyses were performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). Data are expressed as mean ± standard error (mean ± SE). For all cases, $p < 0.05$ (one sided) was considered statistically significant.

3. Results

Both systolic and diastolic blood pressure were significantly lower after forest therapy (systolic blood pressure: before, 140.1 mmHg, after, 123.9 mmHg; diastolic blood pressure: before, 84.4 mmHg, after, 76.6 mmHg; $p < 0.01$) in middle-aged males with high-normal blood pressure (Figure 2). Similarly, both urinary adrenaline (with urinary creatinine correction) (before, 13.1 μg/g creatinine; after, 11.0 μg/g creatinine; $p < 0.05$) (Figure 3) and serum cortisol (before, 7.4 μg/dL; after, 4.9 μg/dL; $p < 0.01$) (Figure 4) were significantly lower after forest therapy.

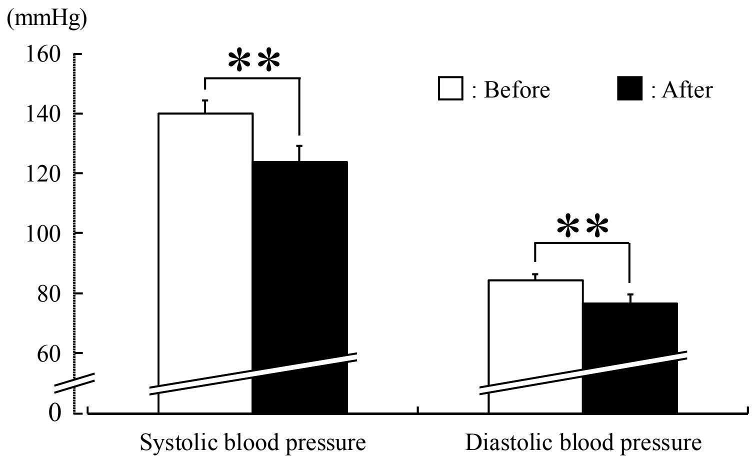


Figure 2. Effect of forest therapy on systolic and diastolic blood pressures in middle-aged males with high-normal blood pressure. N = 9, mean ± standard error. ** $p < 0.01$, paired t-test.

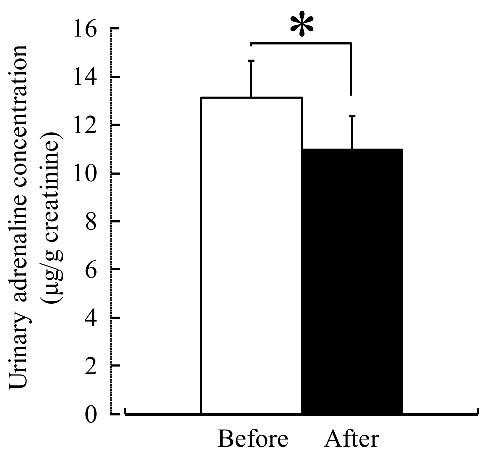


Figure 3. Effect of forest therapy on urinary adrenaline levels. N = 9, mean ± standard error. * $p < 0.05$, paired t-test.

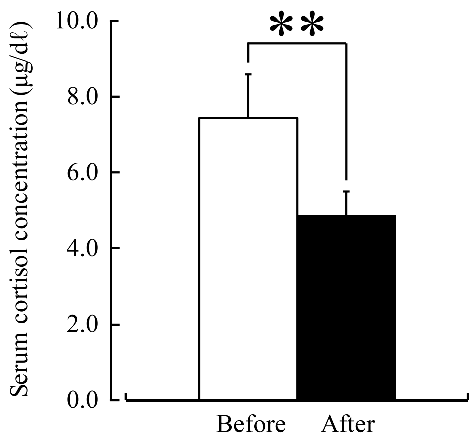


Figure 4. Effect of forest therapy on serum cortisol levels. N = 9, mean ± standard error. ** $p < 0.01$, paired t-test.

Significantly higher semantic differential (SD) scores were observed for the adjectives "relaxed" ($p < 0.01$) and "natural" ($p < 0.05$) after forest therapy as compared with baseline (Figure 5). Finally, a significant elevation of mood was detected on the POMS test (Figure 6), with scores for the negative subscales "tension-anxiety" ($p < 0.01$) , "confusion," and "anger-hostility" and the TMD significantly lower after forest therapy ($p < 0.05$).

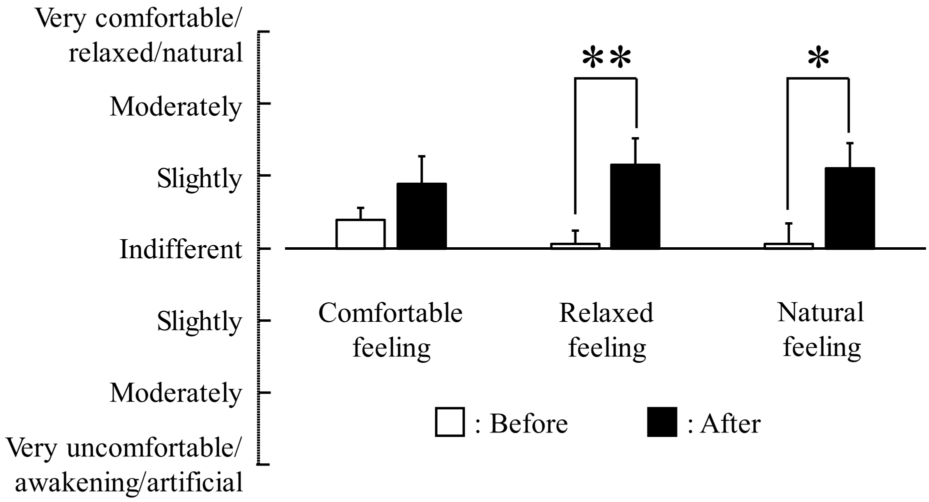


Figure 5. Semantic Differential (SD) method scores before and after forest therapy. Changes in the subjective feelings "comfortable," "relaxed," and "natural." $N = 9$, mean ± standard error. ** $p < 0.01$, * $p < 0.05$, Wilcoxon signed-rank test.

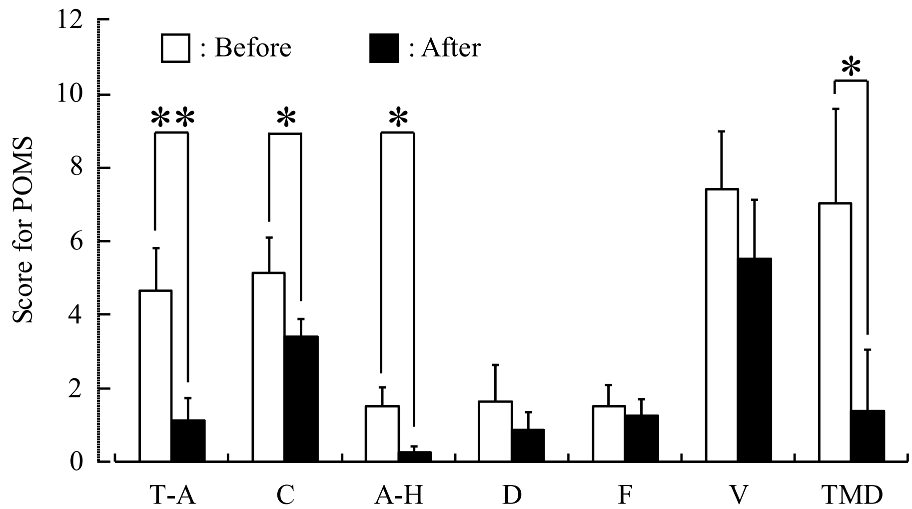


Figure 6. Subjective Profile of Mood State (POMS) scores before and after forest therapy. T-A, tension-anxiety; C, confusion; A-H, anger-hostility; D, depression; F, fatigue; V, vigor; TMD, Total Mood Disturbance. $N = 8$, mean ± standard error. ** $p < 0.01$, * $p < 0.05$, Wilcoxon signed-rank test.

4. Discussion

This study assessed the physiological and psychological benefits of forest therapy on middle-aged Japanese men with high-normal blood pressure. Japanese guidelines for the management of hypertension

(2014) [13] classify less than 140/90 mmHg as normal blood pressure and over 140/90 mmHg as high blood pressure. We enrolled only subjects diagnosed with "high-normal blood pressure" according to this definition. In general, the results were consistent with previous studies showing that forest therapy reduces multiple physiological and psychological indices of stress in healthy young adults [2,6,7]. Moreover, Li *et al.* reported that forest bathing significantly increased NK activity and decreased the concentration of adrenaline in urine, while a city tourist visit had no such effects [14]. However, the activities included in their forest therapy program were impossible to perform in an urban area, including meditation in front of a waterfall, embracing a tree, and the act of thinning of forest experiences. While the current study was preliminary in that we had no control group (*i.e.*, both visiting the forest and visiting an urban area were not compared), we provide evidence for both physiological and psychological benefits in middle-aged patients at risk for hypertension. Regular forest therapy may thus prevent progression to clinical hypertension, a possibility warranting further investigation.

As blood pressure and many other physiological indices show a circadian rhythm, we paid special care to conduct pre- and post-treatment measurements at the same time (mid-afternoon) on successive days. Thus, circadian variation did not contribute to the changes reported. Forest therapy (including a leisurely walk and relaxation in a forest) reduced systolic blood pressure, urinary adrenaline, and serum cortisol. Blood pressure is under dual regulation by the sympathetic and parasympathetic nervous systems, with sympathetic activity increasing and parasympathetic activity reducing blood pressure [15]. Sympathetic activity can be determined by measuring the levels of urinary adrenaline and/or noradrenaline [16], and there are significant correlations between blood pressure and both urinary adrenaline and noradrenaline [15]. Moreover, many previous studies have shown that reducing stress decreases systemic cortisol [17] and sympathetic activity [17]. Thus, forest therapy may lower systolic and diastolic blood pressure of middle-aged males with high normal blood pressures by reducing sympathetic activity, consistent with previous studies on young healthy adults using multiple measures of stress response and autonomic activity, including cortisol and heart rate variability [3,5,6].

According to the SD and POMS questionnaires, participants felt more "comfortable," "natural," and "relaxed" after forest therapy. In addition, negative emotions were significantly reduced. Similarly, younger healthy subjects reported being significantly more comfortable and calm after walking in a forest compared to urban walks [18].

The risks of all cardiovascular diseases, strokes, myocardial infarction, chronic kidney disease, and associated risks of mortality increase in parallel with blood pressure above the optimum [19]. Thus, even patients with high-normal blood pressure benefit from methods that lower blood pressure. This patient group does not need antihypertensive agents; however, modification of lifestyles factors (such as a high sodium diet), weight loss, and exercise are recommended. The current study suggests that regular forest therapy is a convenient option to lower blood pressure into the optimal range and possibly to prevent progression to hypertension and associated complications.

From the viewpoint of public health, it is necessary to shift blood pressure downward in the entire population and not only in high-risk hypertensive patients [20]. Because forests occupy 67% of the land in Japan, they are easily accessible. Thus, forest therapy can be an effective and beneficial treatment for people of all ages and backgrounds. It is expected that broader application of forest therapy will improve the general health of the nation and reduce public medical expenses.

The present study provides evidence of physiological and psychological benefits of forest therapy for middle-aged males with high-normal blood pressure. However, the limitations of the present study include a lack of a control group performing similar activities in an urban environment. Furthermore, these results cannot yet be extrapolated to females or hypertensive adults. Studies examining health benefits in these groups are warranted in future study.

5. Conclusions

Our study revealed that forest therapy elicited a significant: (1) decrease in systolic and diastolic blood pressure; (2) decrease in urinary adrenaline and serum cortisol levels; (3) increase in "relaxed" and "natural" feelings as assessed by the modified SD method; and (4) decrease in POMS negative subscales "tension-anxiety," "confusion," and "anger-hostility" as well as the TMD score in middle-aged males with high-normal blood pressure. Forest therapy may prevent progression to hypertension, thereby reducing associated risks of cardiovascular and renal diseases in this patient group.

Acknowledgments

This study was conducted as a research project from the Vehicle Racing Commemorative Foundation.

Author Contributions

Hiroko Ochiai contributed to data acquisition, interpretation of results, and manuscript preparation. Harumi Ikei and Chorong Song contributed to the experimental design, data acquisition, statistical analysis, and interpretation of results. Maiko Kobayashi and Ako Takamatsu conducted data acquisition. Takashi Miura contributed to preparing the experimental sites and cooperated with data acquisition. Takahide Kagawa and Qing Li participated in data acquisition and contributed to the interpretation of results. Shigeyoshi Kumeda and Michiko Imai conceived the study and participated in the interpretation of results. Yoshifumi Miyazaki conceived and designed the study, contributed to the interpretation of results, and manuscript preparation. All authors have read and approved the final version submitted for publication.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Lederbogen, F.; Kirsch, P.; Haddad, L.; Streit, F.; Tost, H.; Schich, P.; Wust, S.; Pruessner, J.C.; Rietsshel, M.; Deuschle, M.; *et al.* City living and urban upbringing affect neural social stress processing in humans. *Nature* **2011**, *474*, 498–501.
2. Song, C.; Ikei, H.; Tsunetsugu, Y.; Lee, J.; Kagawa, T.; Miyazaki, Y. Physiological and psychological impacts of walking stress in an urban environment on young males. *J. Geogr. Nat. Disast.* **2013**, *32*, doi:10.1186/1880-6805-32-18.

3. Park, B.J.; Tsunetsugu, Y.; Kasetani, T.; Hirano, H.; Kagawa, T.; Sato, M.; Miyazaki, Y. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest)-using salivary cortisol and cerebral activity as indicators. *J. Physiol. Anthropol.* **2007**, *26*, 123–128.
4. Miyazaki, Y.: Shinrinyoku kara Shinrinigaku he. In *Shinrinigaku II*; Ooi, G., Miyazaki, Y., Hirano, H., Eds.; Asakurashoten: Tokyo, Japan, 2009; pp. 23–32. (In Japanese)
5. Tsunetsugu, Y.; Lee, J.; Park, B.J.; Tyrväinen, L.; Kagawa, T.; Miyazaki, Y. Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements. *Landsc. Urban Plan.* **2013**, *113*, 90–93.
6. Lee, J.; Park, B.J.; Tsunetsugu, Y.; Ohira, T.; Kagawa, T.; Miyazaki, Y. Effect of forest bathing on physiological and psychological responses in young male subjects. *Public Health* **2011**, *125*, 93–100.
7. Lee, J.; Tsunetsugu, Y.; Takayama, N.; Park, B.J.; Li, Q.; Song, C.; Komatsu, M.; Ikei, H.; Tyrvainen, L.; Kagawa, T.; *et al.* Influence of forest therapy on cardiovascular relaxation in young adults. *Evid.-Based Complement. Altern. Med.* **2014**, doi:10.1155/2014/834360.
8. Li, Q.; Kobayashi, M.; Inagaki, H.; Hirata, Y.; Li, Y.J.; Hirata, K.; Shimizu, T.; Suzuki, H.; Katsumata, M.; Wakayama, Y.; *et al.* A day trip to a forest park increases human natural killer activity and the expression of anti-cancer proteins in male subjects. *J. Bio. Regul. Homeost. Agents* **2010**, *24*, 157–165.
9. Kaplan, R.; Kaplan, S. *The Experience of Nature. A Psychological Perspective*; Cambridge University Press: New York, NY, USA, 1989.
10. Park, B.J.; Furuya, K.; Kasetani, T.; Takayama, N.; Kagawa, T.; Miyazaki, Y. Relationship between psychological responses and physical environment in forest settings. *Landsc. Urban Plan.* **2011**, *102*, 24–32.
11. Osgood, C.E.; Suchi, G.J.; Tannenbaum, P. *The Measurement of Meaning*; University of Illinois Press: Urbana, IL, USA, 1957.
12. McNair, D.M.; Lorr, M.; Droppleman, L. *Profile of Mood States Manual*; Educational and Industrial Testing Service: San Diego, CA, USA, 1992.
13. Shimamoto, K.; Ando, K.; Fujita, T.; Hasebe, N.; Higaki, J.; Horiuchi, M.; Imai, Y.; Imaizumi, T.; Ishimitsu, T.; Ito, M.; *et al.* The Japanese Society of Hypertension Committee for Guidelines for the Management of Hypertension. *Hypertens. Res.* **2014**, *7*, 253–390.
14. Li, Q.; Morimoto, K.; Kobayashi, M.; Inagaki, H.; Katsumata, M.; Hirata, Y.; Hirata, K.; Suzuki, H.; Li, Y.J.; Wakayama, Y.; *et al.* Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. *Int. J. Immunopathol. Pharmacol.* **2008**, *21*, 117–127.
15. Mena-Martin, F.J.; Martin-Escudero, J.C.; Simal-Blanco, F.; Carretero-Ares, J.L.; Arzua-Mouronte, D.; Castrodeza, Sanz, J.J.; *et al.* Influence of sympathetic activity on blood pressure and vascular damage evaluated by means of urinary albumin excretion. *J. Clin. Hypertens. (Greenwich)* **2006**, *8*, 619–624.
16. Frankenhauser, M. Experimental approach to the study of catecholamines and emotion. In *Emotions, Their Parameters and Measurement*; Levi, L., Ed.; Raven Press: New York, NY, USA, 1975; p. 209.

17. Kirschbaum, C.; Hellhammer, D.H.: Salivary cortisol in psychoneuroendocrine research: Recent developments and applications. *Psychoneuroendocrinology* **1994**, *19*, 313–333.
18. Yamaguchi, M.; Deguchi, M.; Miyazaki, Y. The effects of exercise in forest and urban environments on sympathetic nervous activity of normal young adults. *J. Int. Med. Res.* **2006**, *34*, 152–159.
19. Fujiyoshi, A.; Ohkubo, T.; Miura, K.; Murakami, Y.; Nagasawa, S.Y.; Okamura, T.; Ueshima, H.; Observational Cohorts in Japan (EPOCH-JAPAN) Research Group. Blood pressure categories and long term risk of cardiovascular disease according to age group in Japanese men and women. *Hypertens. Res.* **2012**, *35*, 947–953.
20. Whelton, P.K.; He, J.; Appel, L.J. National High Blood Pressure Education Program Coordinating Committee. Primary prevention of hypertension: Clinical and public health advisory from The National High Blood Pressure Education Program. *JAMA* **2002**, *288*, 1882–1888.

平成26年度

森林浴による健康増進等に関する調査研究

報告書

千葉大学環境健康フィールド科学センター

宮崎良文

目次

はじめに

森林セラピー研究は、日本において1990年代に始まり、ここ10年間で多くの生理データが蓄積されてきた。これまでの森林セラピー研究においては、宮崎良文が中心となり、700名を越える生理的リラックス効果に関するデータが提出されており、これは世界に類を見ない傑出した科学的蓄積である。加えて、李卿が中心となり、免疫機能改善効果に関する極めて学術的レベルの高いデータも提出されており、多くの注目を集めている。

一方、森林セラピーによる生理的リラックス効果に関するデータは20代の健康な男性を中心として、都市における活動との差異を中心として蓄積されてきた。しかし、社会への還元を念頭においた場合、半健康人、未病状態にある方々におけるデータの蓄積が求められているのが現状である。

2013年度においては、代表的な「未病者」である高血圧中高年男性を被験者として、木曽赤沢休養林にて実験を実施した。

本年度は、中高年女性を被験者として、同様の森林セラピー実験を実施した。

Ⅰ 森林浴2日タイプ実験

（1）方法

1）実験デザイン

以下に実験デザインの概略を示す。被験者を2群に分け、1日目、第１群は森林部に行って森林浴を行い、第２群は対照としての都市部に行って、同じ運動量にて同じ歩行、座観を行う。２日目は異なる実験地に行って歩行、座観実験を実施する。

以下に、森林部における実験スケジュールの詳細を示す。

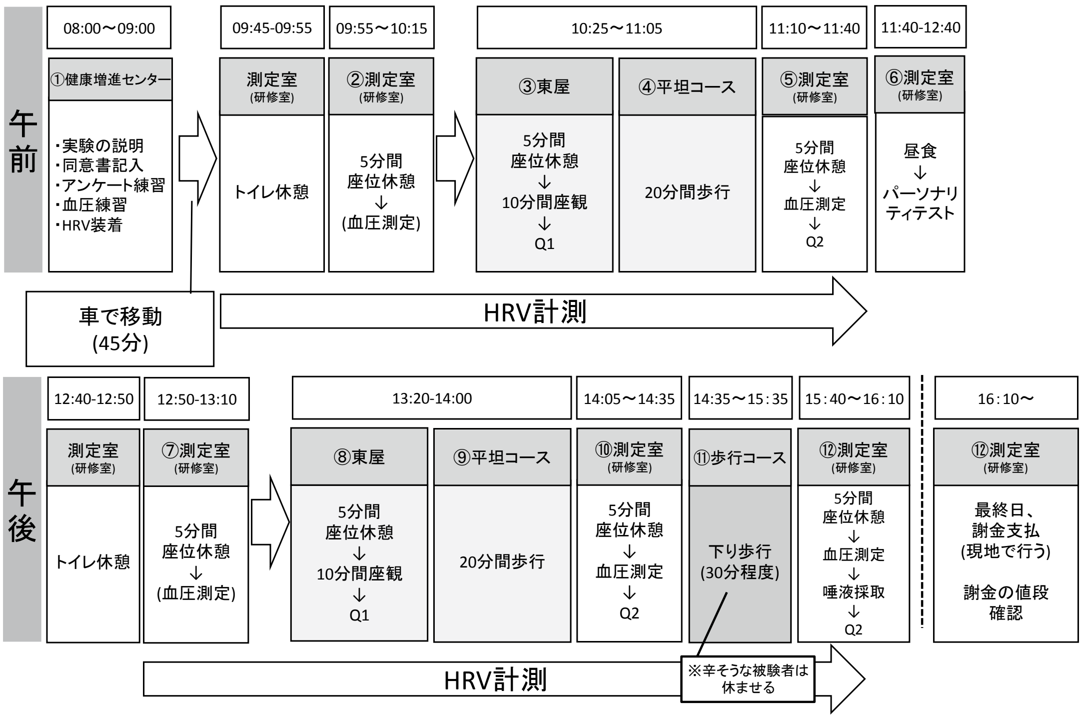
2 日間の実験デザインとし、1 日目、2 日目の森林部ならびに都市部滞在時における 15 分間の座観ならびに 15 分間の歩行時に計測する。

座観、歩行は午前、午後に実施し、計4回の計測を行う。さらに、午後の歩行実験終了後、60分の森林セラピープログラムを実施する

森林部実験スケジュールならびに都市部実験スケジュールをPPT1、2に示す。

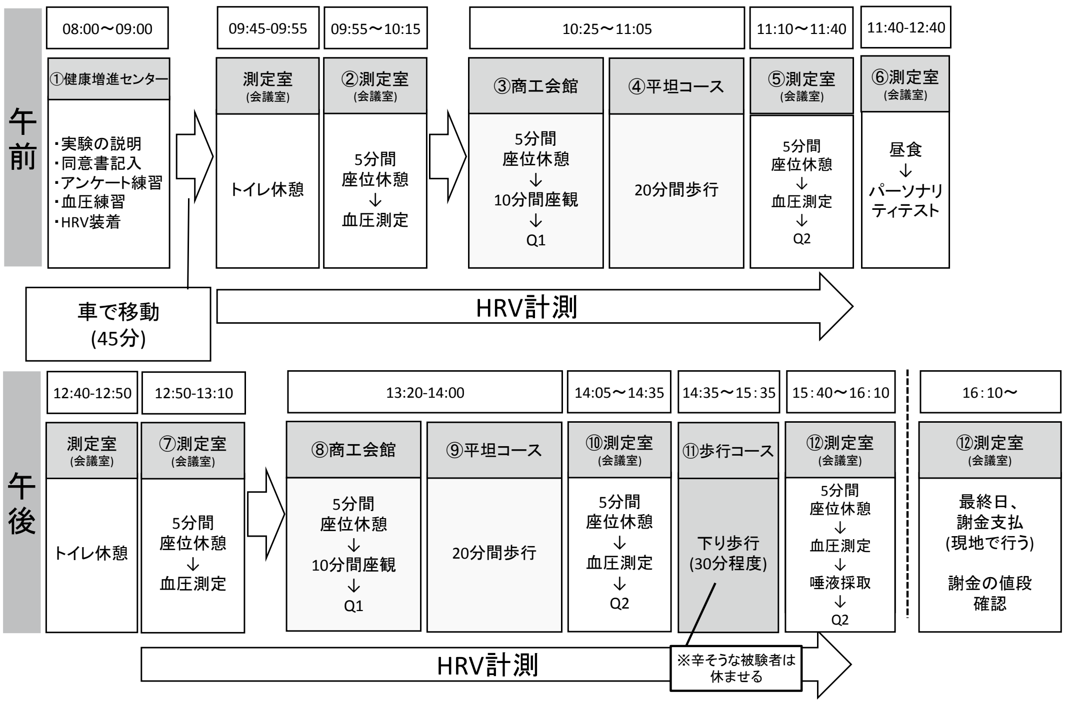
2日タイプ・実験スケジュール・詳細(森林)

＜質問紙＞
Q1：SD
Q2:SD+POMS(3尺度)



2日タイプ・実験スケジュール・詳細(都市)

＜質問紙＞
Q1：SD
Q2:SD+POMS(3尺度)



2）被験者情報

以下に被験者情報一覧を示す。

長野県立木曽病院に通院中の境界域高血圧の未病状態の方々とし、被験者は中高年・高齢女性20名とした。

2日タイプ・被験者情報(女性)

sub	年齢	身長	体重	薬	タバコ	備考	タイプA行動パターン	STAI特性不安
1	65	158	58	×	×		typeB	normal
2	64	162	60	×	×		typeA	high
3	67	154	52	○	×	高血圧薬	typeB	high
4	67	150	45.6	×	×		typeB	normal
5	69	154	58	○	×	高血圧薬、コレステロール系低下薬	typeB	normal
6	69	154	54.5	×	×		typeA	high
7	73	149	54	○	×	高脂血症薬、糖尿病薬	typeB	high
8	71	158	59	○	×	高血圧薬、末梢性交感神経抑制薬	typeB	normal
9	70	154	55	×	×		typeB	normal
10	70	146	65	○	×	高血圧薬、狭心症薬	typeA	normal
11	72	143.5	64	○	×	高血圧薬、狭心症薬	typeB	high
12	77	152	63.5	○	×	高血圧薬、末梢血管拡張薬、コレステロール系低下薬	typeB	normal
13	74	146	49	×	×		typeB	normal
14	−	−	−	−	−	欠席	−	−
15	63	151	70	○	×	高血圧薬、狭心症薬、コレステロール系低下薬	typeB	high
16	70	158	66	×	×		typeB	high
17	69	152	40	○	×	高血圧薬、末梢血管拡張薬	typeB	high
18	56	152	72	×	○		typeA	high
19	53	151	65	×	×		typeB	normal
20	50	157	55.6	×	×		typeA	high
mean	66.9	152.4	58.2					
SD	7.3	4.7	8.4					
SE	1.7	1.1	2.0					

3）実験風景

森林部

座観①

森林部

座観②

森林部

座観③

都市部

座観①

都市部

座観②

都市部

座観③

森林部

歩行①

森林部

歩行②

森林部

歩行③

森林部

歩行④

都市部

歩行①

都市部

歩行②

都市部

歩行③

都市部

歩行④

森林部

血圧測定

都市部

血圧測定

4）測定手法

森林セラピー用の実験地は、赤沢自然休養林とし、比較のための対象地は伊那市と都心部とした。

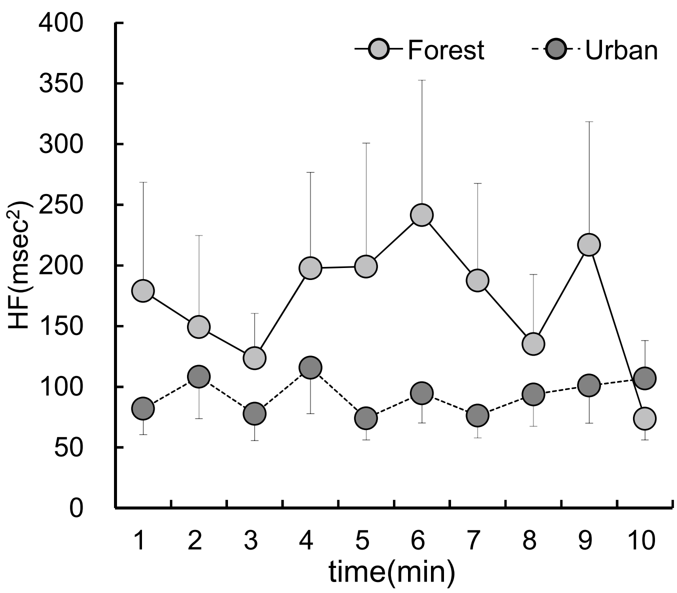
測定指標は、心拍変動性（毎分計測）、心拍数（毎秒計測）、血圧（刺激前後計測）、脈拍数（刺激前後計測）、唾液中コルチゾール濃度（刺激後計測）とした。

(2) 結果と考察

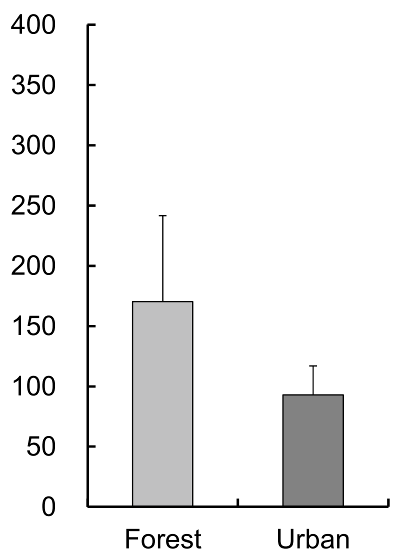
1）座観実験

①午前座観実験

下記に示すように午前中の 10 分間の座観によって、心拍変動性、副交感神経活動には有意差は認められなかったが、高まる傾向にあった。

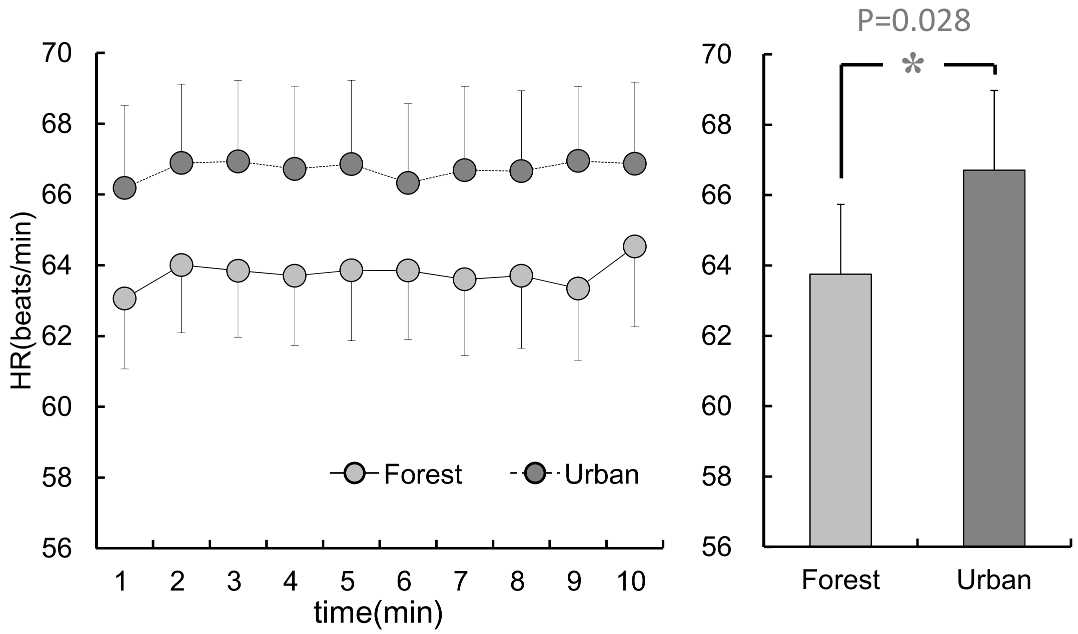


N=12, mean±SE



N=12, mean±SE,
対応のあるt検定(片側)

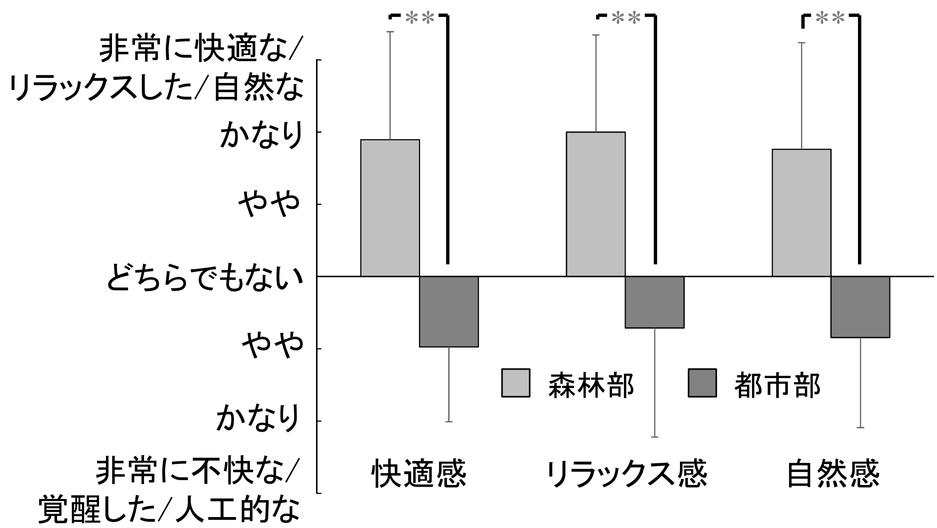
一方、心拍数は森林部において、都市部に比べ、有意に低いことがわかった。



N=18, mean±SE

N=18, mean±SE, *p<0.05
対応のあるt検定(片側)

簡易型 SD 法による主観評価においては、森林セラピーによって、有意に「快適で」「リラックスし」「自然である」と感じられていた。



N=19, mean±SD, **: p<0.01, ウィルコクソン符号付順位和検定(片側, Holm補正)

以上より、森林部午前座観（10 分間）は、都市部座観に比べ、

1）生理的には

①心拍数を減少させること

2）心理的には

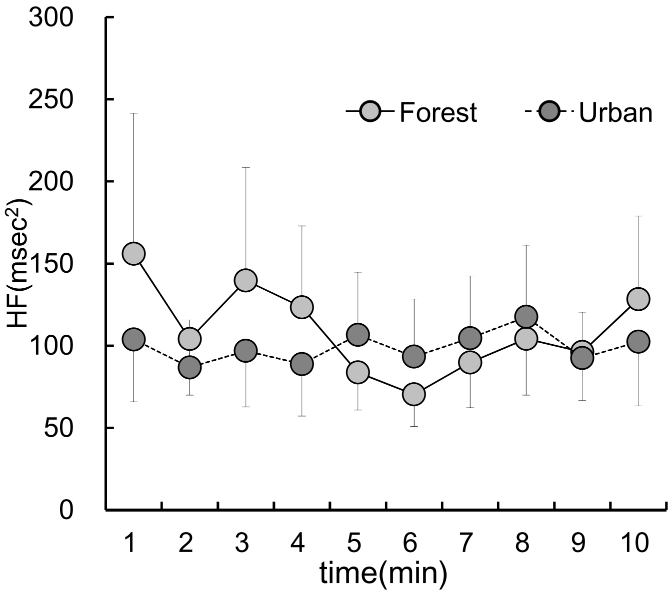
①「快適感」「鎮静感」「自然感」を高めること

が明らかとなった。

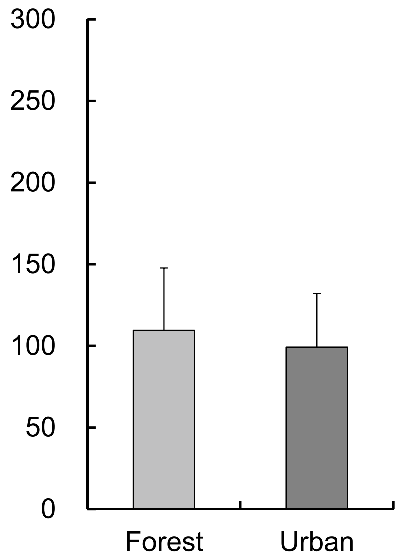
結論として、午前の森林部座観は生理的・心理的にリラックス状態をもたらすことが分かった。

②午後座観実験

下記に示すように午後の 10 分間の森林座観によって、心拍変動性における副交感神経活動には差異が認められなかった。

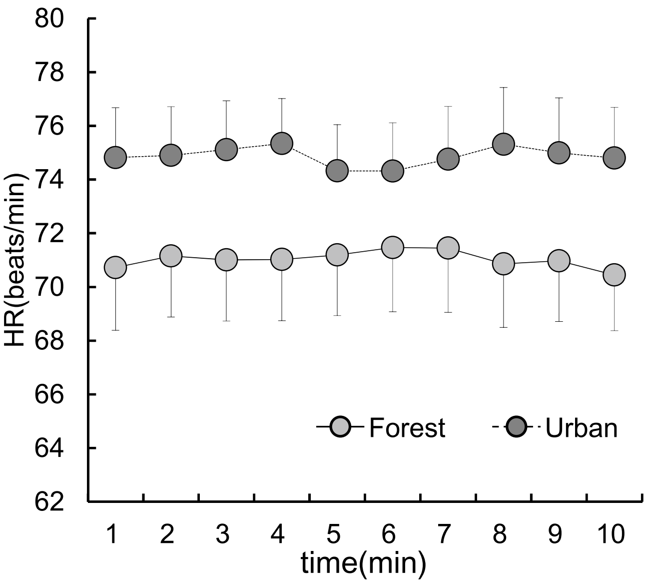


N=13, mean±SE

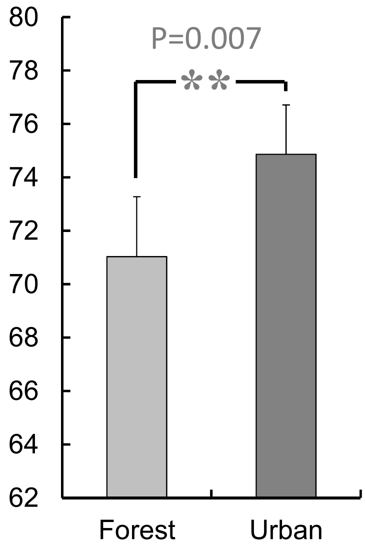


N=13, mean±SE,
対応のあるt検定(片側)

午後の 10 分間の森林座観は心拍数の低下ももたらすことがわかった。

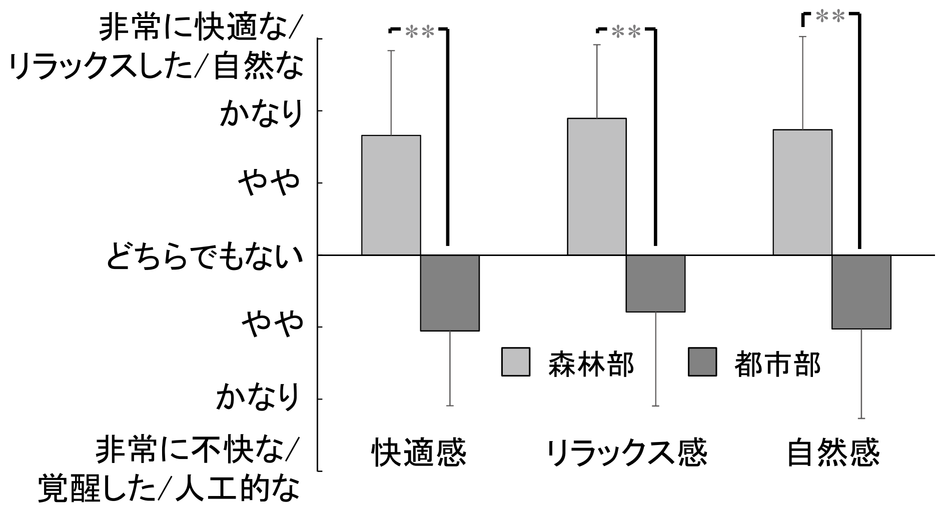


N=19, mean±SE



N=19, mean±SE, **p<0.01
対応のあるt検定(片側)

さらに、簡易型 SD 法による主観評価においては、森林セラピーによって、有意に「快適で」「リラックスし」「自然である」と感じられていた。



N=19, mean±SD, **: p<0.01, ウィルコクソン符号付順位和検定(片側, Holm補正)

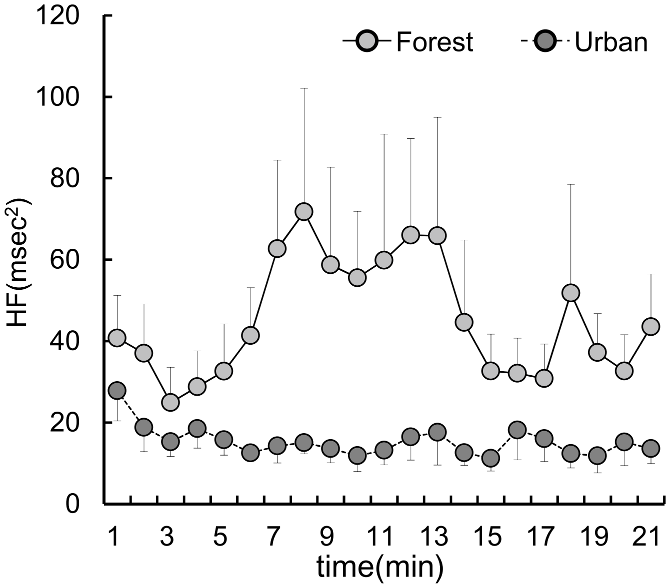
以上より、森林部午後座観（10 分間）は、都市部座観に比べ、
1）生理的には
①心拍数を減少させること
2）心理的には
①「快適感」「鎮静感」「自然感」を高めること
が明らかとなった。

結論として、午後の森林部座観は生理的・心理的にリラックス状態をもたらすことが分かった。

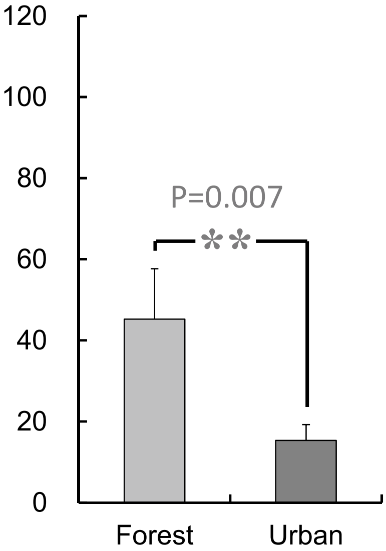
2）歩行実験

①午前歩行実験

下記に示すように、午前の 21 分間の森林歩行において、心拍変動性における副交感神経活動は有意に高まることがわかった。

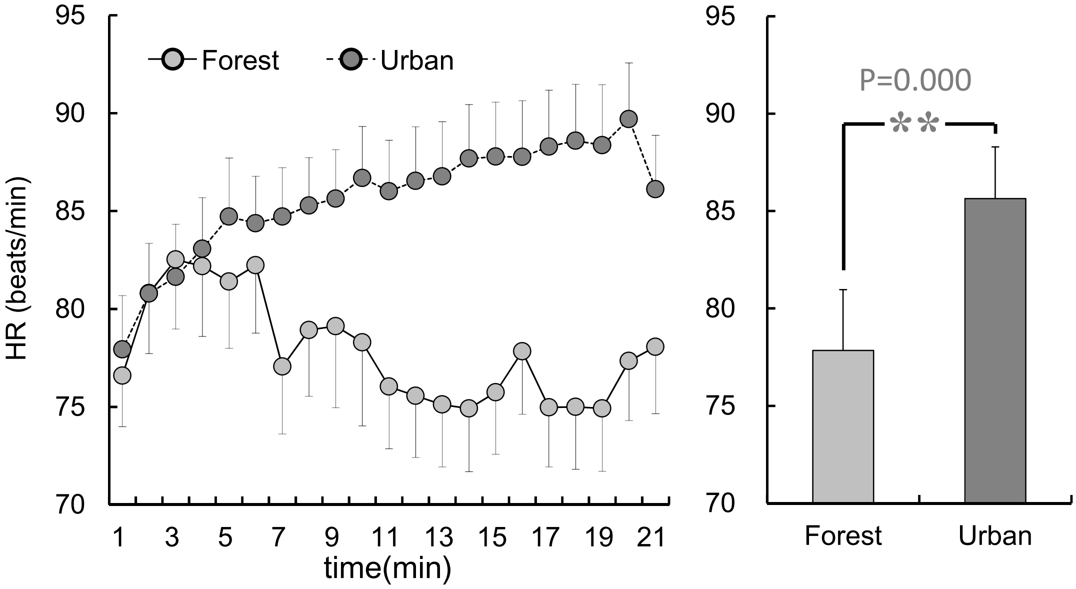


N=9, mean±SE



N=18, mean±SE, **p<0.01
対応のあるt検定(片側)

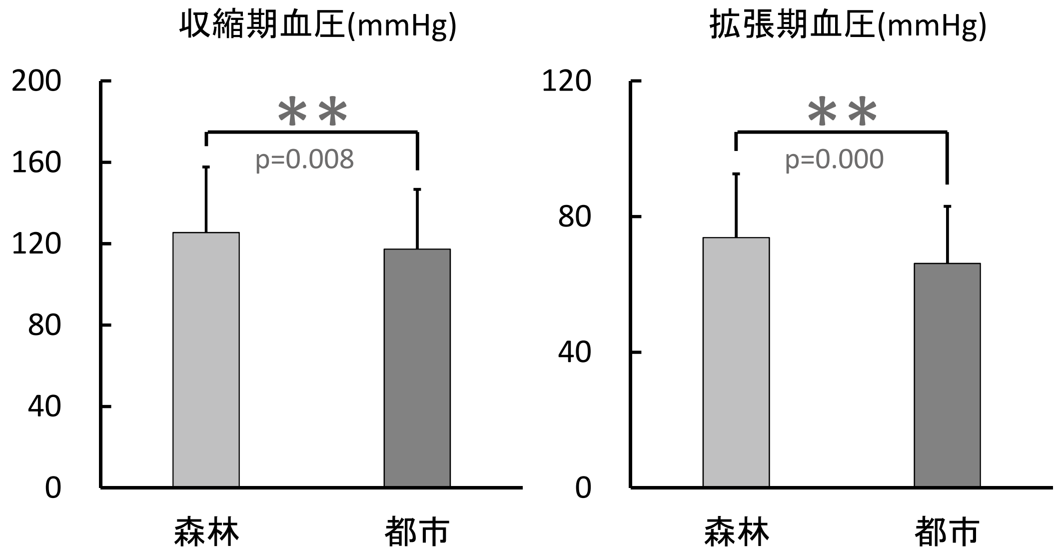
同様に、森林歩行によって心拍数も有意に低下した。



N=18, mean±SE

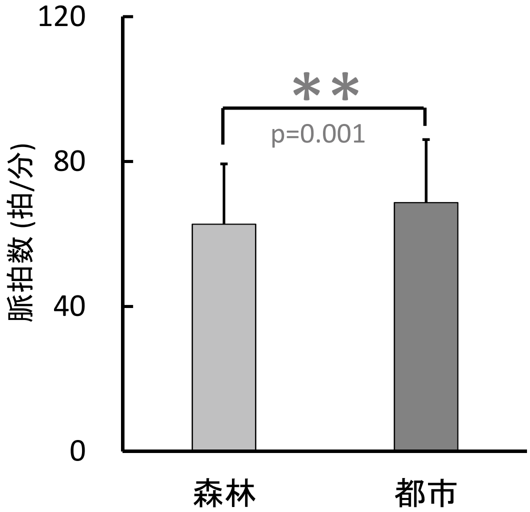
N=18, mean±SE, **p<0.01
対応のあるt検定(片側)

以下に午前21分間の森林歩行後の血圧の変化を示す。収縮期血圧ならびに拡張期血圧ともに有意に高まったが正常範囲内の変化であった。



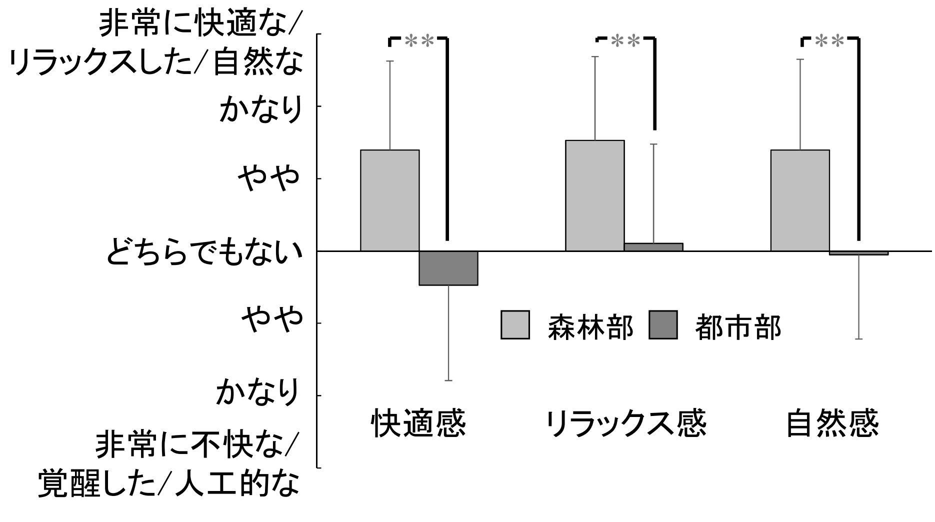
N=19, mean±SD, **: p<0.01, t検定(対応あり・片側)

森林歩行後の脈拍数は有意に低下することが認められた。



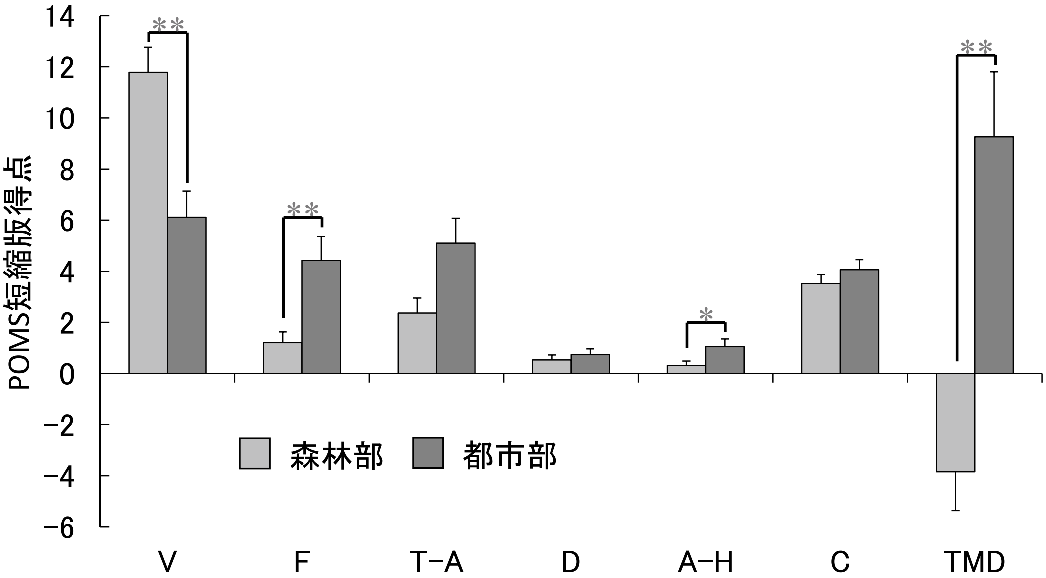
N=19, mean±SD, **: p<0.01, t検定(対応あり・両側)

以下に午前 21 分間の森林歩行後の簡易 SD 法（「快適感」「鎮静間」「自然感」）を示す。森林歩行によって、快適で、鎮静的で、自然であると感じられていることが明らかとなった。



N=19, mean±SD, **: p<0.01, ウィルコクソン符号付順位和検定(片側, Holm補正)

加えて、森林歩行後の感情プロフィール検査（POMS）においても、「活気」が有意に高まり、「疲労」、「怒り-敵意」が有意に低下し「総合感情障害」も有意に低下することが明らかとなった。



N=21, mean±SD, **$p<0.01$,*$p<0.05$, ウィルコクソン符号付順位和検定(片側)
V:活気, F:疲労, T−A：緊張−不安, D:抑うつ−落込み, A−H：怒り−敵意,
C：混乱, TMD：総合感情障害

以上より、森林部午前歩行（21 分間）は、都市部歩行に比べ、

1）生理的には

①歩行中の副交感神経活動（心拍変動性）を有意に高めること

②歩行中の心拍数を有意に減少させること

③歩行後の脈拍数を有意に低下させること

2）心理的には

①「快適感」「鎮静感」「自然感」を有意に高めること

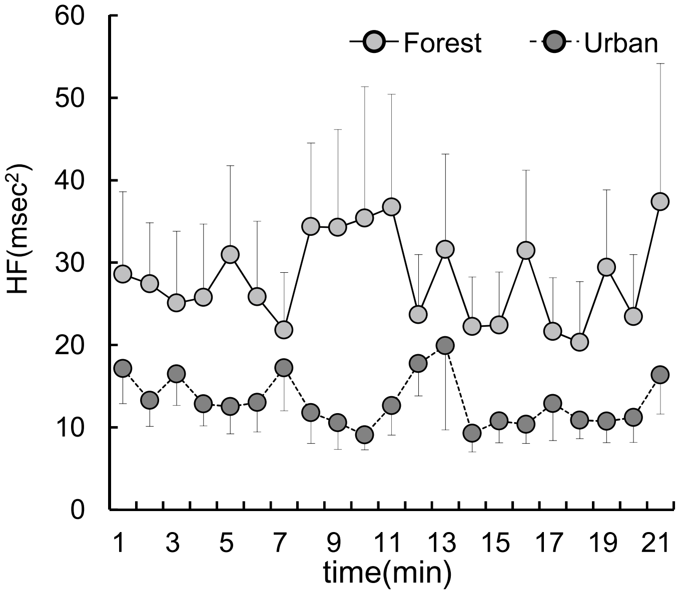
②POMS の「活気感」を高め、「疲労」、「怒り-敵意」、「総合感情障害」を有意に低下させること

が認められた。

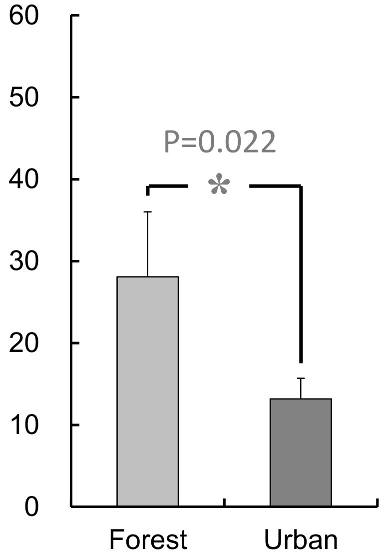
結論として、午前の森林部歩行は生理的・心理的にリラックス状態をもたらすことが明らかとなった。

②午後歩行実験

下記に示すように、午後の 21 分間の森林歩行において、心拍変動性における副交感神経活動は有意に高まることがわかった。

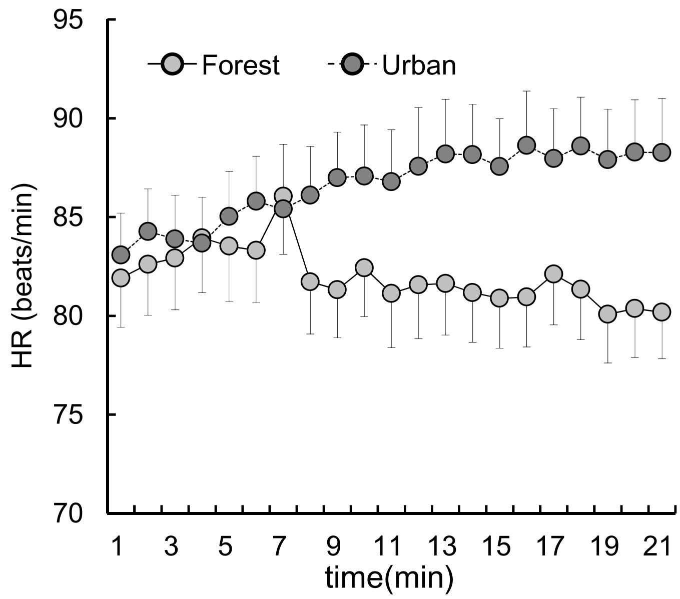


N=11, mean±SE

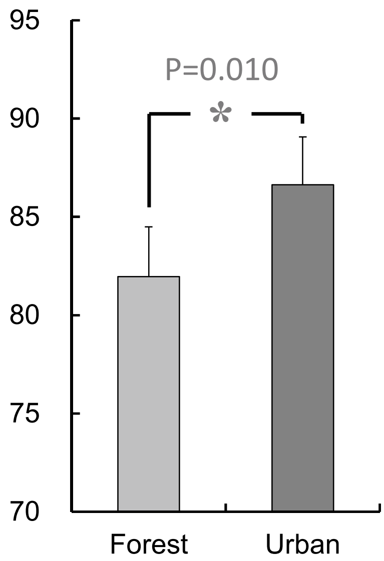


N=11, mean±SE, **p<0.01
対応のあるt検定(片側)

同様に、森林歩行によって心拍数も有意に低下した。

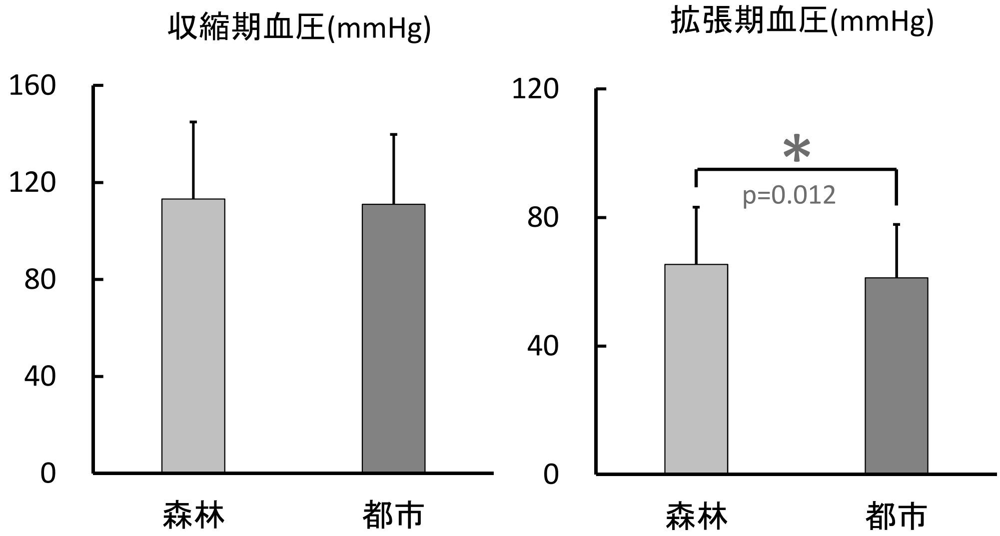


N=18, mean±SE



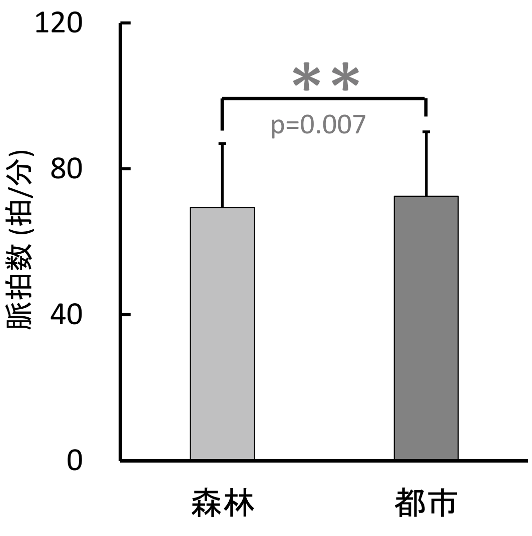
N=18, mean±SE, **p<0.01
対応のあるt検定(片側)

以下に午後 21 分間の森林歩行後の血圧の変化を示す。拡張期血圧は有意に上昇したが、正常値に近づく変化であった。



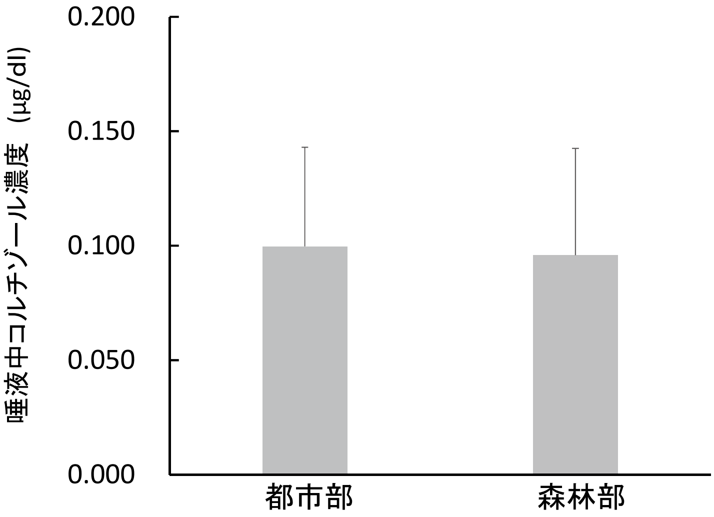
N=19, mean±SD, *: p<0.05, t検定(対応あり・片側)

一方、森林歩行後の脈拍数は有意に低下することが認められた。



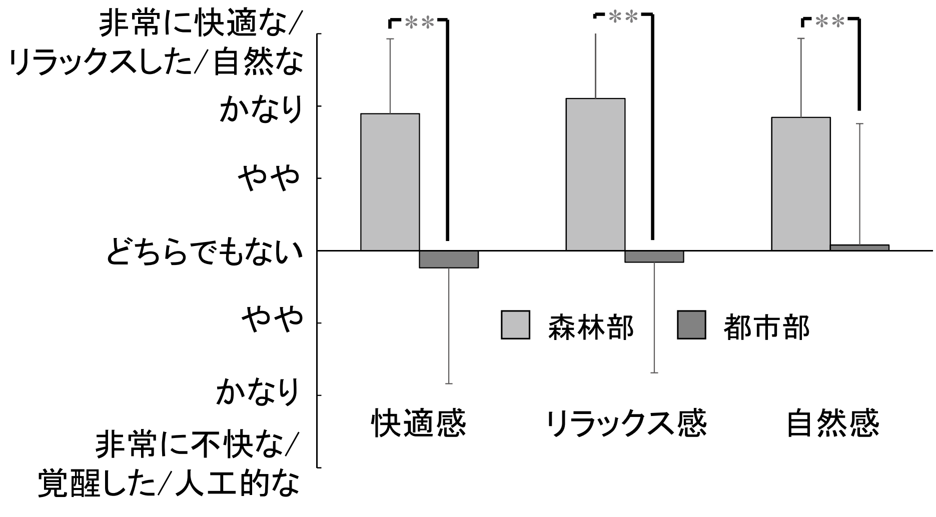
N=19, mean±SD, **: p<0.01, t検定(対応あり・両側)

森林歩行後のコルチゾール濃度には差異がなかった。



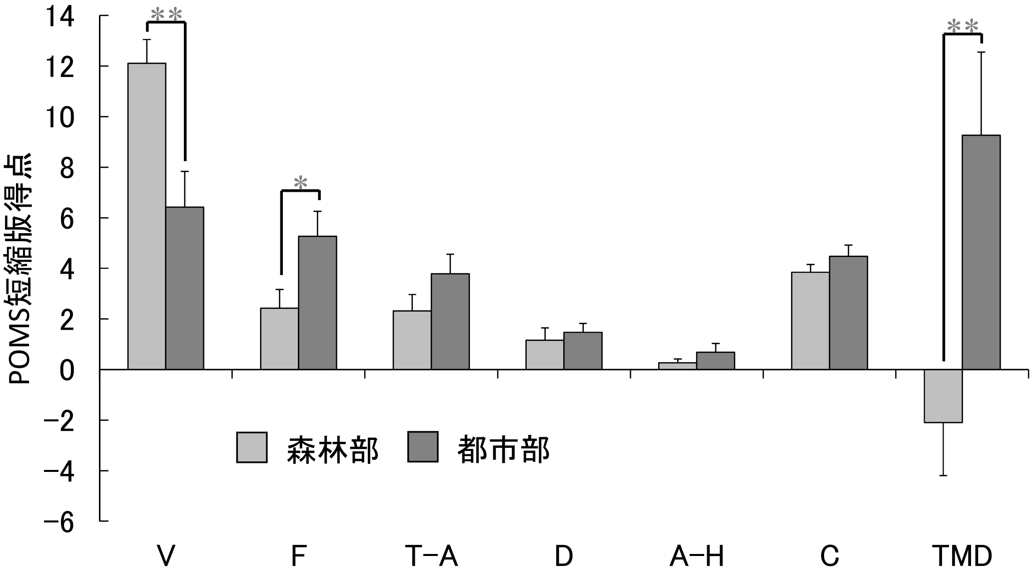
N=18, mean±SD, 対応のあるt検定(片側)

以下に午後 21 分間の森林歩行後の簡易 SD 法（「快適感」「鎮静間」「自然感」）を示す。森林歩行によって、快適で、鎮静的で、自然であると感じられていることが明らかとなった。



N=19, mean±SD, **: p<0.01, ウィルコクソン符号付順位和検定(片側, Holm補正)

加えて、森林歩行後の感情プロフィール検査（POMS）においても、「活気」が有意に高まり、「疲労」、「総合感情障害」が有意に低下することが明らかとなった。



N=21, mean±SD, **p<0.01,*p<0.05, ウィルコクソン符号付順位和検定(片側)
V:活気, F:疲労, T−A：緊張−不安, D:抑うつ−落込み, A−H：怒り−敵意,
C：混乱, TMD：総合感情障害

以上より、森林部午後歩行（21 分間）は、都市部歩行に比べ、

1）生理的には

①歩行中の副交感神経活動（心拍変動性）を有意に高めること

②歩行中の心拍数を有意に減少させること

③歩行後の脈拍数を有意に低下させること

2）心理的には

①「快適感」「鎮静感」「自然感」を有意に高めること

②POMS の「活気感」を高め、「疲労」、「総合感情障害」を有意に低下させること

が認められた。

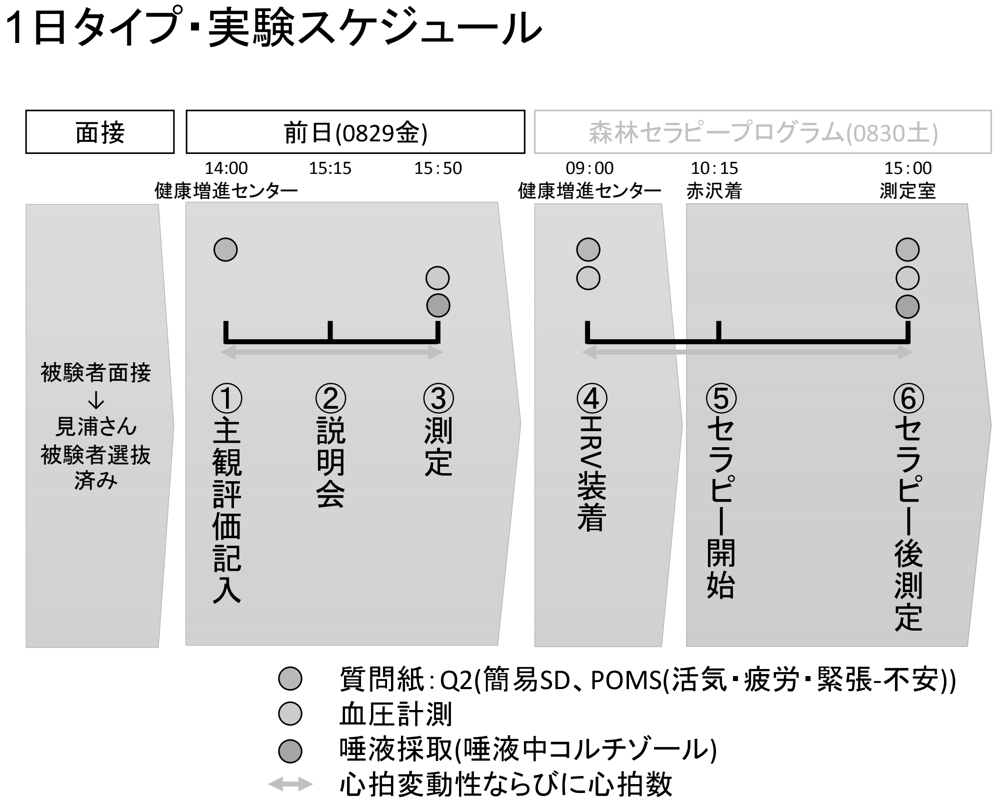
結論として、午前の森林部歩行は生理的・心理的にリラックス状態をもたらすことが明らかとなった。

Ⅱ 森林浴 **1** 日タイプ実験

（**1**）方法

1）実験デザイン

以下に森林浴1日タイプの実験デザインの概略を示す。



2）被験者情報

被験者は中高年・高齢女性19名とした。

1日タイプ・被験者情報(女性)

sub	年齢	身長	体重	薬	タバコ	備考	パーソナリティ
1	40	158	53	×	×		typeB
2	42	155	46	×	×	「前日」は欠席/唾液なし	typeB
3	65	156	74	○	×	高血圧薬、狭心症薬、利尿薬	typeB
4	50	157	50	×	×		typeA
5	47	163	47	×	×		typeB
6	66	161	49	○	○	コレステロール系低下薬	typeB
7	61	155	64	×	×		typeB
8	71	152	43	○	×?	高血圧薬、抗アレルギー薬	typeB
9	72	145	45	○	×	高血圧薬、狭心症薬、冠血管拡張薬、心筋梗塞薬	typeB
10	69	151	72	○	×	高血圧薬、コレステロール系低下薬	typeB
11	64	157	61	○	×	高血圧薬、狭心症薬	typeB
12	73	154	55	×	×		typeB
13	73	152	52	○	×	高血圧薬、狭心症薬、コレステロール系低下薬	typeB
14	63	157	47	×	×		typeB
15	56	158	63	×	×		typeA
16	64	151	52	○	×	コレステロール吸収抑制薬、トリグリセリド系低下薬	typeB
17	65	159	44	○	×	排尿改善薬、抗アレルギー薬	typeB
18	59	151	54	×	×		typeB
19	47	154	55	×	×	「前日」は欠席/唾液なし	typeB
mean	**60.4**	**155.1**	**54.0**				
SD	10.5	4.2	9.0				
SE	2.4	1.0	2.1				

3）実験風景

解説①

解説②

解説③

散策①

散策②

散策③

散策④

仰臥位①

仰臥位②

仰臥位③

仰臥位④

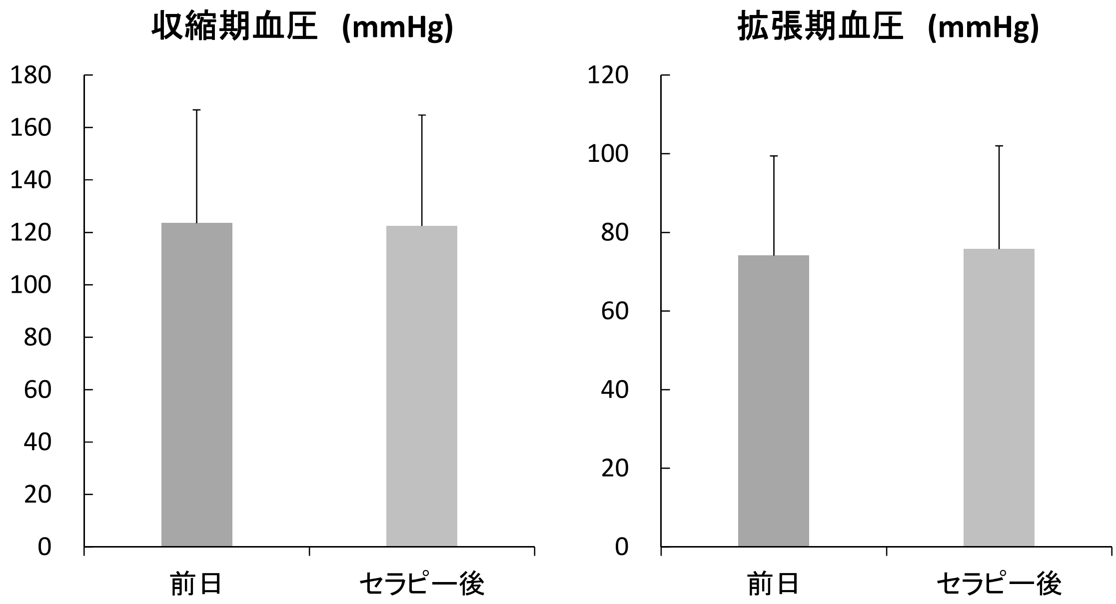
4） 測定手法

測定手法は森林浴 2 日タイプ実験と同様とした。

（2） 結果と考察

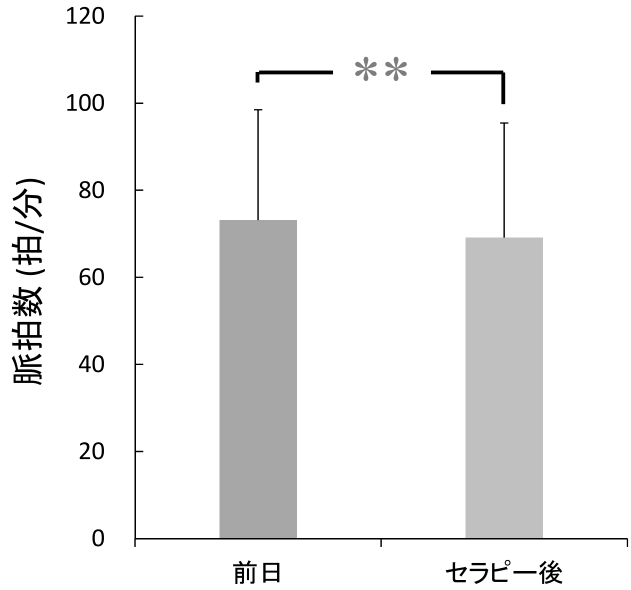
1） 森林セラピープログラム実験

森林セラピープログラム後の血圧に変化は認められなかった。



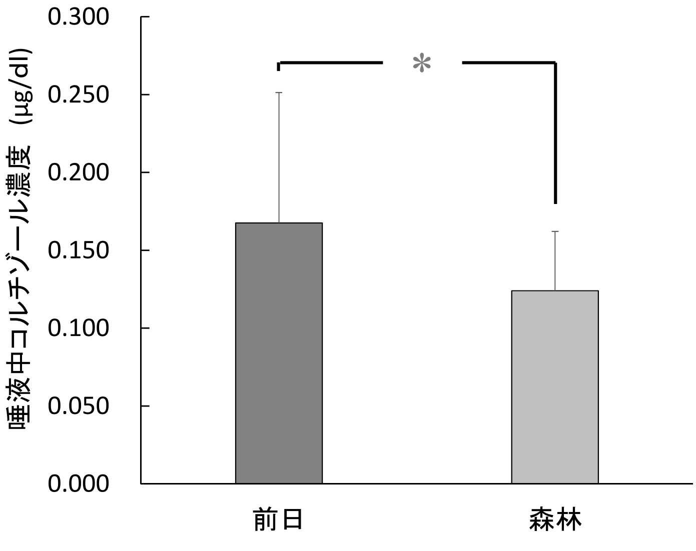
N=17, mean±SD, 対応のあるt検定(片側)

一方、脈拍数は、有意に低下していることがわかった。



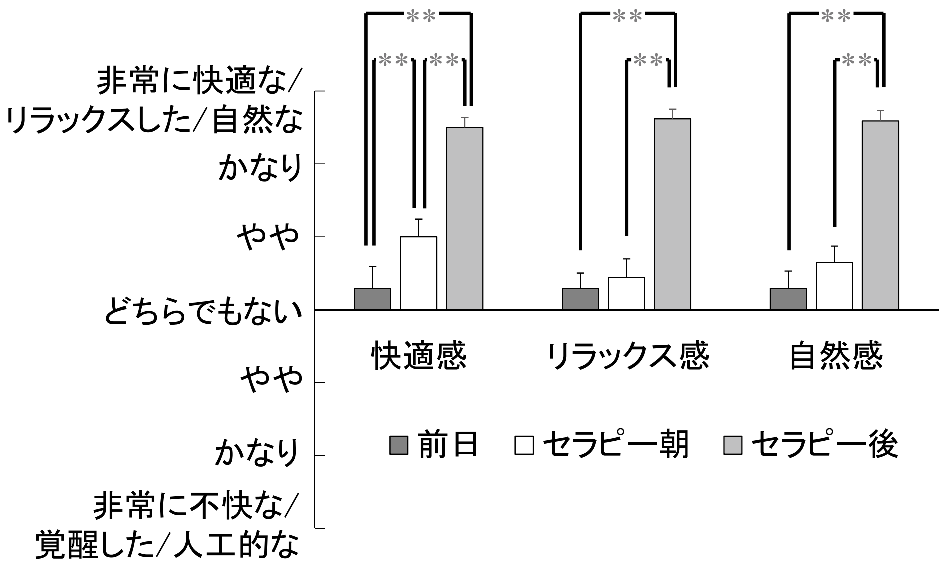
N=17, mean±SD, **: p<0.01, 対応のあるt検定(片側)

下記に唾液中コルチゾール濃度の結果を示す。血圧同様、前日の対照に比べ、有意に低下することが認められた。



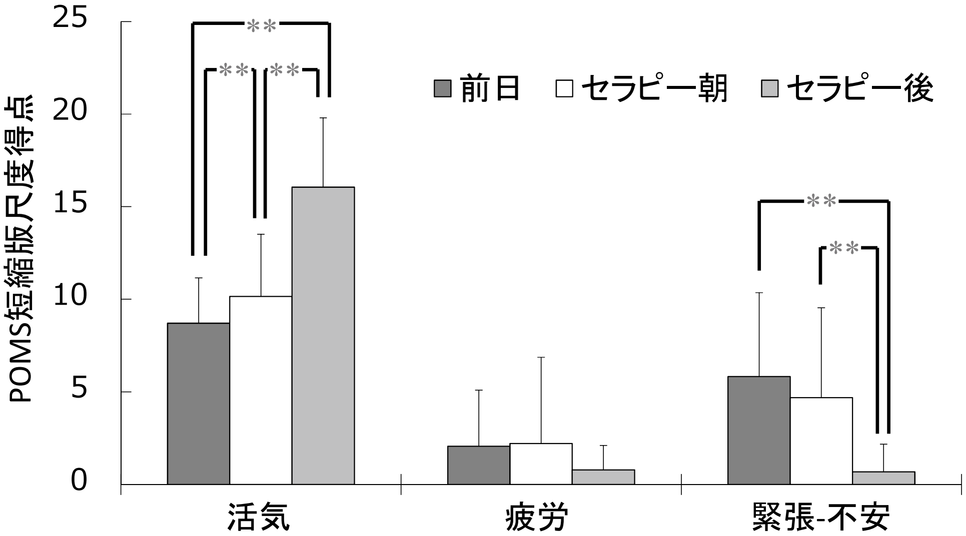
N=17, mean±SD, *: p<0.05, 対応のあるt検定(片側)

以下に森林セラピー後の簡易 SD 法（「快適感」「鎮静間」「自然感」）を示す。森林セラピーによって、前日ならびに森林セラピー前に比べて、快適で、鎮静的で、自然であると感じられていることが明らかとなった。



N=17, mean±SE, **: p<0.01, ウィルコクソン符号付順位和検定(片側, Holm補正)

加えて、森林歩行後の感情プロフィール検査（POMS）においても、「活気」が有意に高まり、「緊張-不安」が有意に低下することが明らかとなった。



N=17, mean±SE, **: p<0.01, ウィルコクソン符号付順位和検定(片側, Holm補正)

以上より、1 日タイプ森林セラピープログラム実験によって、前日の同時刻における測定結果に比べ

1）生理的には

①歩行後の脈拍数を有意に低下させること

②歩行後の唾液中コルチゾール濃度を有意に低下させること

2）心理的には

①「快適感」「鎮静感」「自然感」を有意に高めること

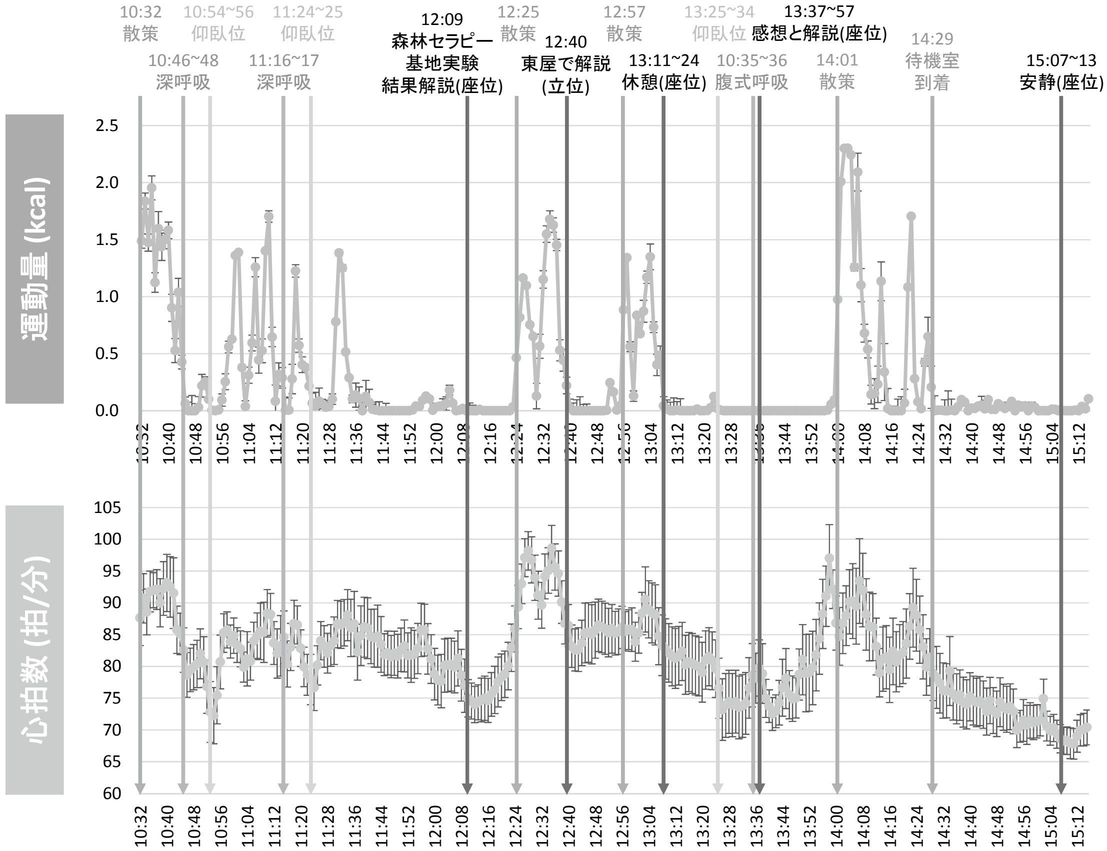
②POMS の「活気感」を高め、「緊張-不安」を有意に低下させること

が認められた。

結論として、1 日タイプ森林セラピープログラムは生理的・心理的リラックス効果をもたらすことが分かった。

2）森林セラピー時運動量と生理指標の関係

運動量と心拍数の関係を以下に示す。運動量の増加と心拍数の増大には強い相関があることを認められた。



おわりに
平成 26 年度実験の成果は以下の通りである。

（1）森林浴 2 日タイプ実験においては、

1）中高年女性被験者における森林歩行は生理的ならびに主観的リラックス効果をもたらすことが明かとなった。

本成果は、インパクトファクター誌に投稿予定である。

2）中高年女性被験者における森林内座観は生理的ならびに主観的リラックス効果をもたらすことが明かとなった。

本成果も、インパクトファクター誌に投稿予定である。

（2）森林浴 1 日タイプ実験においては、

1）中高年女性被験者 1 日森林セラピープログラムは生理的ならびに主観的リラックス効果をもたらすことが明かとなった。

本成果は、以下の論文としてインパクトファクター2. 1 の雑誌に掲載された。

＝＝＝

Physiological and psychological effects of a forest therapy program on middle-aged females

H. Ochiai, H. Ikei, C. Song, M. Kobayashi, T. Miura, T. Kagawa, Q. Li, S. Kumeda, M. Imai and Y. Miyazaki

International Journal of Environmental Research and Public Health 12(12): 15222-15232 2015

＝＝＝

本研究は以下のメーバーの協力の元に実施された（五十音順）。
池井晴美（国立研究開発法人森林総合研究所）
今井通子（医師、国際自然・森林医学会長）
落合博子（国立病院機構東京医療センター）
香川隆英（国立研究開発法人森林総合研究所）
久米田茂喜（長野県立木曽病院名誉院長）
小林麻衣子（日本医科大学）
宋チョロン（千葉大学環境健康フィールド科学センター）
高松亜子（国立成育医療研究センター）
見浦崇（長野県上松町）
李卿（日本医科大学）

International Journal of
Environmental Research and Public Health

MDPI

Communication

Physiological and Psychological Effects of a Forest Therapy Program on Middle-Aged Females

Hiroko Ochiai [1,†], Harumi Ikei [2,3,†], Chorong Song [2,†], Maiko Kobayashi [4], Takashi Miura [5], Takahide Kagawa [3], Qing Li [4], Shigeyoshi Kumeda [6], Michiko Imai [7] and Yoshifumi Miyazaki [2,*]

Received: 18 September 2015; Accepted: 25 November 2015; Published: 1 December 2015
Academic Editor: Paul B. Tchounwou

1 Department of Plastic and Reconstructive Surgery, National Hospital Organization, Tokyo Medical Center, Tokyo 152-8902, Japan; ochiroko@gmail.com
2 Center for Environment, Health and Field Sciences, Chiba University, Chiba 277-0882, Japan; ikei0224@ffpri.affrc.go.jp (H.I.); crsong1028@chiba-u.jp (C.S.)
3 Forestry and Forest Products Research Institute, Ibaraki 305-8687, Japan; kagawa@ffpri.affrc.go.jp
4 Department of Hygiene and Public Health, Nippon Medical School, Tokyo 113-8602, Japan; mk831111@nms.ac.jp (M.K.); qing-li@nms.ac.jp (Q.L.)
5 Agematsu Town Office Industry & Tourism Department, Nagano 399-5601, Japan; agkk5180@gmail.com
6 Nagano Prefectural Kiso Hospital, Nagano 397-8555, Japan; kumeda@titan.ocn.ne.jp
7 Le Verseau Inc., Tokyo 156-0051, Japan; leverseau@mvb.biglobe.ne.jp
* Correspondence: ymiyazaki@faculty.chiba-u.jp; Tel.: +81-4-7137-8113; Fax: +81-4-7137-8008
† These authors contributed equally to this work.

Abstract: The natural environment is increasingly recognized as an effective counter to urban stress, and "Forest Therapy" has recently attracted attention as a relaxation and stress management activity with demonstrated clinical efficacy. The present study assessed the physiological and psychological effects of a forest therapy program on middle-aged females. Seventeen Japanese females (62.2 ± 9.4 years; mean ± standard deviation) participated in this experiment. Pulse rate, salivary cortisol level, and psychological indices were measured on the day before forest therapy and on the forest therapy day. Pulse rate and salivary cortisol were significantly lower than baseline following forest therapy, indicating that subjects were in a physiologically relaxed state. Subjects reported feeling significantly more "comfortable," "relaxed," and "natural" according to the semantic differential (SD) method. The Profile of Mood State (POMS) negative mood subscale score for "tension–anxiety" was significantly lower, while that for "vigor" was significantly higher following forest therapy. Our study revealed that forest therapy elicited a significant (1) decrease in pulse rate, (2) decrease in salivary cortisol levels, (3) increase in positive feelings, and (4) decrease in negative feelings. In conclusion, there are substantial physiological and psychological benefits of forest therapy on middle-aged females.

Keywords: forest therapy program; middle-aged females; pulse rate; salivary cortisol; semantic differential method; Profile of Mood State

1. Introduction

The term "forest bathing" was proposed in Japan in 1982, and penetrated as words to express for enjoying the comfort of the forest. However, there was little information regarding "What is so psychologically comforting about the forest?" and "What specific psychological and physiological changes are taking place in a body in the forest?" The elucidation of the phenomenon rapidly advanced around the past 10 years, and it developed into the term "forest therapy" programs. Indeed, "forest therapy" is now increasingly recognized as an effective relaxation and stress management activity with demonstrated a preventive medical effect and increased healthy effect among healthy Japanese adults [1].

Several studies have shown that time spent in a forest can decrease blood pressure (BP) [2–6], pulse rate [2–7], sympathetic nervous activity [4–6,8–10], and cortisol levels [2–5,7,8,11,12], while increasing parasympathetic nervous activity [3–10]. Furthermore, forest stimulation decreased cerebral blood flow in the prefrontal cortex [12], and Bratman *et al.* reported that a brief nature experience decreased both self-reported rumination and neural activity in the subgenual prefrontal cortex (sgPFC) [13]. These studies suggest that accessible natural areas are a critical resource for improving mental health in our rapidly urbanizing world [13].

It was also shown that a forest therapy trip can increase human natural killer (NK) cell activity and improve immunity in both males and females, and these effects were found to last for at least 7 days [14–17]. Additionally, psychological studies have demonstrated that the negative mood was significantly lower and the positive mood was significantly higher after durations of stay in the forest [10,18].

Park *et al.* reported relaxation and stress-management effects of forest environments using several questionnaire-based metrics, in addition to improved mood [19]. In psychological tests of young adult males, forest therapy significantly increased positive feelings and reduced negative feelings in comparison with urban stimuli [2–4,6,8–12]. A majority of studies involving forest therapy experiments report the various effects in male subjects [4,8–10,19–21]; however, few reports have focused on female subjects [16].

Most field experiments on forest therapy have enrolled only healthy young adults as subjects, while those who need these benefits the most may be older adults at a higher risk of stress- and lifestyle-related diseases such as high BP, diabetes, and depression. Song *et al.* reported physiological and psychological relaxation effects on hypertensive individuals after a brief walk in the forest [20]; however, few studies have examined the effects of a standardized forest therapy program on higher-risk populations, particularly a program that can be completed within a day for convenience and broad accessibility. To address these issues, we planned experiments to measure the effects of a standardized forest therapy program on middle-aged males with high-normal BP [21] and found that systolic and diastolic BP, urinary adrenaline, and serum cortisol levels were significantly lower than baseline following the program. While this study lacked a control group, it did provide evidence that the physical and psychological benefits of a brief forest therapy program extend to middle-aged males. Here, we investigated the physiological and psychological effects of a standard forest therapy program on middle-aged females (mean age: 62 years) to allow comparison with the previously measured effects on male subjects of similar age.

2. Experimental Section

2.1. Subjects

Seventeen Japanese females ranging in age from 40 to 73 years (62.2 $\pm$ 9.4 years; mean $\pm$ standard deviation) were recruited from the Health Promotion Center in Agematsu, Nagano Prefecture. Inclusion criteria were female aged 40 years or older. Candidates who thought it may be difficult to walk in hot weather were excluded. Six subjects were on medication for hypertension, which was well controlled. All participants were free from other diseases and psychological disorder. Body mass index (BMI) [22,23] was calculated from height and weight (BMI = weight (kg) $\div$ {height (m) $\times$ height (m)) and divided into a BMI $\geqslant$ 25 group and a BMI < 25 group. At 14:00 on the day before the initiation of forest therapy, the subjects gathered in a waiting room at the Health Promotion Center; they were completely informed regarding the study aims and procedures before initiating the experiment. They received a description of the experiment, and all the subjects signed an agreement to participate. After physiological inspections and questionnaires were completed, the subjects disbanded at 16:30. To control for the effects of alcohol, the subjects did not consume alcohol during the entire study period. Participants were directed to perform normal "everyday life" activities on the day before forest therapy. This study was approved by the Ethics Committee of Nagano Prefecture Kiso Hospital and the Center for Environment, Health and Field Sciences, Chiba University, Japan, on 19 August 2013 and performed according to the Declaration of Helsinki [24].

2.2. Experimental Sites

The forest therapy phase was conducted in Akasawa Shizen Kyuyourin (Akasawa Natural Recreation Forest), Agematsu, Nagano Prefecture (situated in central Japan) on 30 August 2014. The distance from the health promotion center to the forest was 14.6 km, and it took 42 min to drive by car. The weather was cloudy on the forest therapy day, with a mean temperature of 21.5 °C (18.2 °C–27.5 °C) and humidity of 81% (49%–96%).

2.3. Physiological Indices

Both systolic and diastolic BP levels and pulse rate readings were obtained from the right arm using a portable digital sphygmomanometer (HEM-1020, Omron, Kyoto, Japan). These procedures were performed between 15:09 and 15:22 on the day before forest therapy and between 14:44 and 14:56 after forest therapy to control for circadian effects.

Salivary cortisol, which shows a reliable increase under stress, was measured as an index of endocrine activity. Saliva samples were collected using a saliva collection aid (No.61/524,096; SalivaBio LLC, California, USA) between 15:28 and 15:35 on the day before forest therapy and between 14:57 and 15:05 after forest therapy. Saliva samples collected at the field site were immediately placed in a freezer and sent to a laboratory (MACROPHI Inc, Takamatsu, Japan) for analysis.

2.4. Psychological Indices

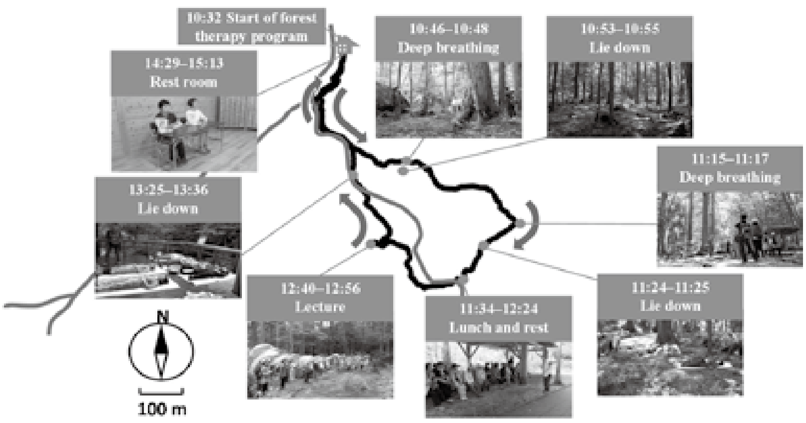
The semantic differential (SD) method and a short form of the Profile of Mood State (POMS) were used to evaluate psychological responses to forest therapy. These questionnaires were completed by subjects between 15:00 and 15:20 on the day before forest therapy and between 14:44 and 14:56 after forest therapy. The SD method uses three pairs of adjectives anchoring seven-point scales: "comfortable to uncomfortable," "relaxed to awakening," and "natural to artificial" [25]. The short form of POMS was used to decrease the burden on the subjects [26]. We assessed three subscales: "tension–anxiety," "fatigue," and "vigor."

2.5. Experimental Design

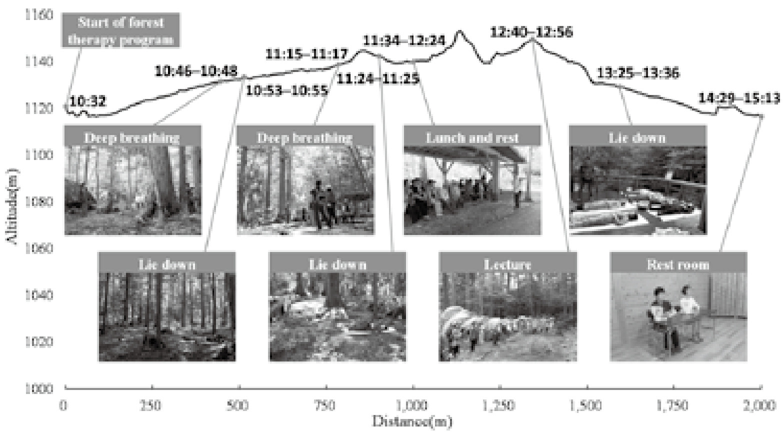
The subjects spent the previous night in their respective homes. On the morning of the forest therapy day, the subjects gathered in the same meeting room at 9:00 and participated in the forest therapy program as a group with a guide. They were not permitted to carry cell phones. The program consisted of multiple timed activities over 4 h and 41 min (Table 1) led by a guide. The subjects walked around their assigned area and then sat and lay on their backs in the forest on waterproof sheets laid on the ground during rest breaks. The guide put on measuring equipment with a map-caching offline GPS application (Geographica, Japan) and accompanied the subjects in the forest (Figure 1a,b).

Table 1. Time schedules and calorie consumption during various activities of the forest therapy program.

Time	Event	Calorie Consumption (Kcal/min)
10:32–10:45	Stroll (Forest)	1.21
10:46–10:48	Deep breathing (Forest)	0
10:49–10:52	Stroll (Forest)	0.15
10:53–10:55	Lie down (Forest)	0
10:56–11:14	Stroll (Forest)	0.65
11:15–11:17	Deep breathing (Forest)	0.10
11:18–11:23	Stroll (Forest)	0.48
11:24–11:25	Lie down (Forest)	0.06
11:26–11:33	Stroll (Forest)	0.52
11:34–12:24	Lunch and rest (Resting room)	0.04
12:25–12:39	Stroll (Forest)	0.92
12:40–12:56	Lecture (Forest)	0.08
12:57–13:09	Stroll (Forest)	0.66
13:10–13:24	Rest (Forest)	0.01
13:25–13:36	Lie down & abdominal breathing (Forest)	0.00
13:37–13:59	Chat (Forest)	0.01
14:00–14:28	Stroll (Forest)	0.76
14:29–15:13	Rest (Resting room)	0.02



(**a**)



(**b**)

Figure 1. Images showing the various activities of the forest therapy program with location map. (**a**): plane map, (**b**): altitude map.

Energy expenditure was assessed for each activity using Lifecorder GS4 (Suzuken Co., Ltd., Chiba, Japan). Tobacco and all drinks (except mineral water) were prohibited during forest therapy. The subjects ate the same lunch made from local ingredients at the same time (11:34–12:24). After the subjects completed the program, they returned to a waiting room for post-treatment measurements and to complete the questionnaires. These results were then compared with those obtained on the previous day.

We aimed to compare the physiological and psychological effects of forest therapy with everyday life activities on a normal day. Physiological and psychological inspections were performed at approximately the same time on the day before and on the day of the therapy.

2.6. Statistical Analysis

We used paired *t*-tests to compare physiological indices and the Wilcoxon signed-rank test to compare psychological test results obtained before and immediately after forest therapy. All statistical analyses were performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). Data are expressed as the mean ± standard error (mean ± SE). For all tests, $p < 0.05$ (one sided) was considered statistically significant.

3. Results

Pulse rate was significantly lower after forest therapy than on the day before forest therapy (baseline) in middle-aged females (69.1 ± 2.7 *vs.* 73.1 ± 2.5 beats/min; $t(16) = 4.67$, $p < 0.01$ by paired *t*-test) (Figure 2). Similarly, salivary cortisol levels were significantly lower after forest therapy than on the day before forest therapy (0.124 ± 0.009 *vs.* 0.168 ± 0. 020 μg/dL; $t(16) = 2.63$, $p < 0.05$ by paired *t*-test) (Figure 3).

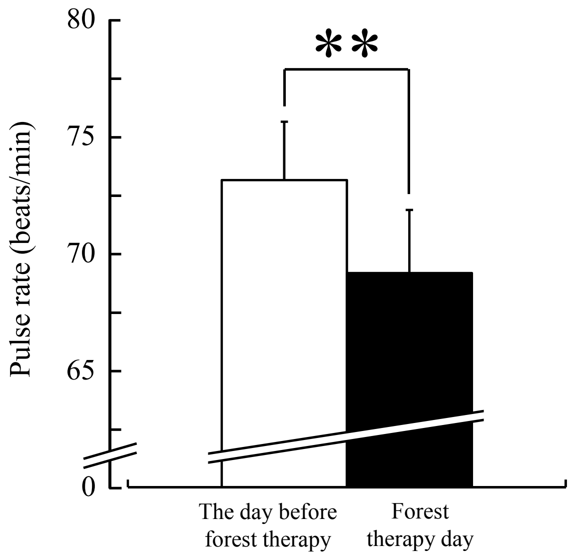


Figure 2. Effect of forest therapy on pulse rate of middle-aged females. N = 17, mean ± standard error. ** $p < 0.01$, paired *t*-test.

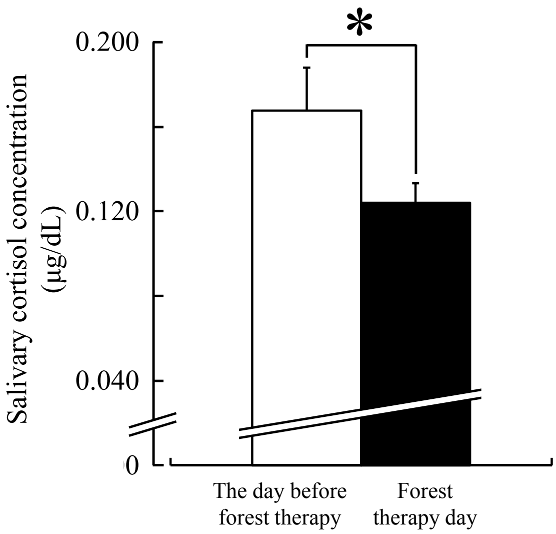


Figure 3. Effect of forest therapy on salivary cortisol level. N = 17, mean ± standard error. * $p < 0.05$, paired *t*-test.

The total energy expenditure during forest therapy was compared between subjects with BMI ⩾ 25 (N = 4) and those with BMI < 25 (N = 13). A marginally significant difference was observed between groups, with 24% greater expenditure in the BMI ⩾ 25 group compared with the BMI < 25 group (0.88 ± 0.08 *vs.* 0.71 ± 0.06 kcal/min; t(15) = 1.88, $p < 0.10$ by unpaired *t*-test). The mean salivary cortisol level was reduced in the BMI < 25 group after forest therapy (0.186 ± 0.024 *vs.* 0.123 ± 0.012μg/dL; t(12) = 3.19, $p < 0.01$ by paired *t*-test), but it actually increased slightly in the BMI ⩾ 25 group (0.109 ± 0.013 *vs.* 0.128 ± 0.014μg/dL; t(3) = 4.01, $p < 0.05$ by paired *t*-test).

Significantly higher SD scores were observed for the adjectives "comfortable" ($p < 0.01$), "relaxed" ($p < 0.01$), and "natural" ($p < 0.01$) after forest therapy than on the day before forest therapy (Figure 4). Finally, a significant elevation of mood was detected on POMS (Figure 5), with scores for the negative subscale "tension–anxiety" being significantly lower ($p < 0.01$) and those for the positive subscale "vigor" ($p < 0.01$) being significantly higher after forest therapy.

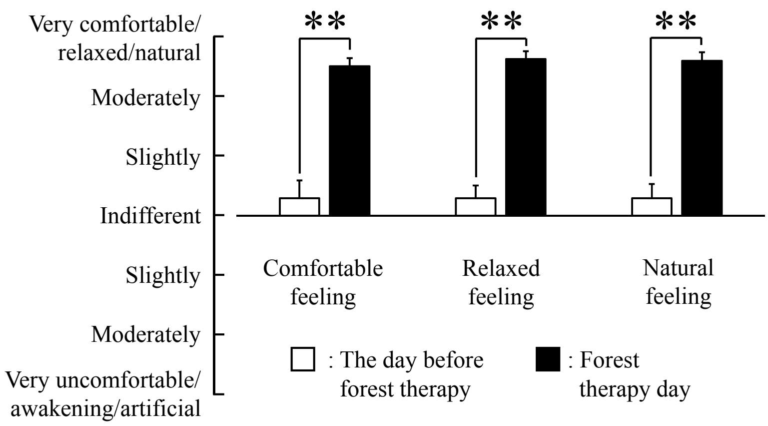


Figure 4. Semantic differential (SD) method scores for the day before forest therapy and immediately after forest therapy, showing changes in the subjective feelings "comfortable," "relaxed," and "natural". N = 17, mean ± standard error. ** $p < 0.01$, Wilcoxon signed-rank test.

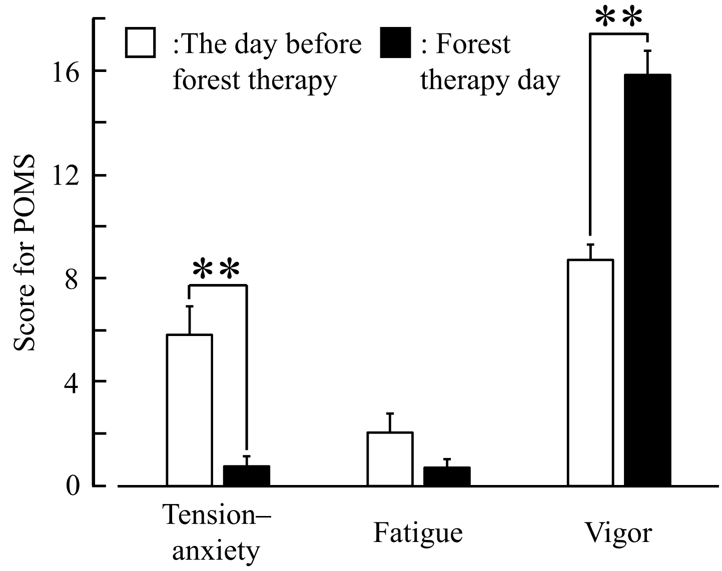


Figure 5. Lower negative and higher positive subjective Profile of Mood State (POMS) subscores after forest therapy than on the day before forest therapy. N = 17, mean ± standard error. ** $p < 0.01$, Wilcoxon signed-rank test.

4. Discussion

The present study assessed the physiological and psychological benefits of forest therapy on middle-aged Japanese females. The mean pulse rate was significantly lower after walking in a forest environment than on the day before forest therapy. Because the pulse rate is a basic index of autonomic nervous system activation, the drop in pulse rate indicates a state of relaxation in middle-aged females, consistent with the past reports that examined physiological responses to a natural environment in young adults [2–7]. Thus, we concluded that this benefit of physiological relaxation extends to middle-aged females.

Sympathetic activity can be determined by measuring the levels of urinary adrenaline and/or noradrenaline [27], and many previous studies have shown that reducing stress decreases sympathetic activity, as measured by systemic cortisol levels [28]. The concentration of cortisol was the highest immediately after waking up and decreases and stabilizes in the afternoon. We used saliva samples for measuring cortisol levels as this method is easily manageable in a field setting and is non-invasive. Furthermore, salivary cortisol provides a reliable prediction of total and calculated free serum cortisol levels [29]. It has been reported that the normal level of salivary cortisol is 0.07–0.73 μg/dL [30]. Many previous studies have shown that lowered stress levels result in lower cortisol levels [2–5,7,8,11,12]; therefore, we conclude that forest therapy also reduces stress in middle-aged females.

For several decades, BMI (kg/m^2) has been used to diagnose obesity in clinical practice and obesity research and to structure programs and goals for weight loss interventions [31]. BMI is sometimes used to estimate total body fat and determine whether a person has a healthy weight. While BMI may not always provide an accurate estimate of excess body fat, BMI $\geqslant 25$ is linked to increased risk of diseases such as heart disease and some cancers. In the present study, the salivary cortisol level was reduced only in subjects with BMI < 25. Note, however, that these measures are derived for a single forest therapy session, which may have been more stressful on the heavier subjects. Therefore, for middle-aged females with high BMI, a sustained regular program may be necessary for the anti-stress benefits to emerge.

The baseline salivary cortisol level was 1.7-fold higher in subjects with BMI < 25 than in those with BMI $\geqslant 25$, but this difference disappeared after forest therapy. Song *et al.* reported that subjects with high initial BP showed a decrease, while those with low initial values showed an increase after walking in a forest area [32]. These results suggest a physiological adjustment effect in the forest environment, which may also account for the normalization of cortisol levels among participants with different BMI. However, no report has studied this adjustment effect for cortisol levels in subjects matched for baseline BMI; therefore, additional studies are necessary.

According to the SD questionnaires, middle-aged females felt more "comfortable," "natural," and "relaxed" after forest therapy. In addition, the negative emotion "tension–anxiety" was reduced and the positive feeling of "vigor" was higher after forest therapy according to the short form of POMS. Similarly, middle-aged males reported feeling significantly more "natural" and "relaxed" after walking in a forest [21]. While "tension–anxiety" was significantly lower after forest therapy in middle-aged males as well, in contrast to middle-aged females, they reported no significant change in "vigor" [21]. Neither group reported changes in "fatigue," although measurement immediately after the forest walk may have contributed to temporary fatigue. Nonetheless, these findings indicate that a single forest therapy session has psychological benefits for both middle-aged women and men.

Although many factors can affect the general condition of menstruating females, little is known about differences in the relationship between physiological and subjective stress responses at various phases of the menstrual cycle [33]. Watanabe *et al.* reported that no significant differences in salivary cortisol levels were observed during any phase of the menstrual cycle [34]. Additionally, the mean age of this study sample was 62 years. However, because the mean age for menopause in Japanese women is approximately 50 years, we did not consider the influence of the menstrual cycle in this experiment. Menopausal disorders are a frequent problem in middle-aged females. Many of these problems may stem from disruption of the intricate links between estrogen metabolism and the autonomic nervous system. Many women gain weight because of the decrease in estrogen and basal metabolism, while autonomic changes may lead to tachycardia and mental health effects. Normal aging influences various indices, and the parasympathetic tone is generally higher in women than men, as evidenced by heart rate variability (HRV) measurements [35]. It has been reported that physical activity facilitates improved HRV stability in older women and that the quantity of exercise training necessary for such an improvement is relatively modest [36].

"Forest therapy" is increasingly recognized not only as a convenient exercise but also as a relaxation and stress management activity with demonstrated clinical benefits [1]. Moreover, we can control the energy expenditure by choosing the appropriate course terrain, distance, and walking speed and by including regular rest and relaxation sessions, such as sitting, lying, and deep breathing. Forest therapy could be an effective and convenient method for the improvement of menopausal symptoms such as autonomic imbalance, stiff shoulder, knee pain, constipation, shortness of breath, and depression. Furthermore, as a group activity, forest therapy is an opportunity to spend time enjoying the natural environment with friends and family.

The present study provides evidence for physiological and psychological benefits of forest therapy in middle-aged females. Limitations of the present study include the lack of a control group performing similar activities in an urban environment. An ideal experimental design would include a comparison of the effects of forest therapy using the same parameters/environmental stimuli, but instead conducting the comparison (control group) in an urban area setting. However, this would be difficult to implement in practice because it involves activities such as "lying down" in an urban area. So the control experiments of the same activities completed indoors are thought to be necessary in future. Interestingly, differences in effect were observed with varying BMI. However, the limited number of subjects in this study decreased the significance of the analysis. Future studies should include a larger number of subjects. Furthermore, forest therapy has not yet been shown to actually reduce the risk of disease independent of the general effects of exercise. It is now necessary to design experiments that test whether forest therapy can reduce disease risk in vulnerable populations through these demonstrated physiological and psychological benefits.

5. Conclusions

Our study revealed that forest therapy elicited a significant (1) decrease in pulse rate, (2) decrease in salivary cortisol levels, (3) increase in "comfortable," "natural," and "relaxed" feelings as assessed by the modified SD method, (4) decrease in the POMS negative subscale "tension–anxiety," and (5) increase in feelings of "vigor" in middle-aged females. In conclusion, walking in a forest according to a standard "forest therapy" program induced physiological and psychological relaxation. These results clarified the physiological effects of the forest therapy program and suggested a possibility of clinical use.

Acknowledgments: This study was conducted as a research project from the Vehicle Racing Commemorative Foundation. We thank Ako Takamatsu for cooperation during this study.

Author Contributions: Hiroko Ochiai contributed to data acquisition, interpretation of results, and manuscript preparation. Harumi Ikei and Chorong Song contributed to the experimental design, data acquisition, statistical analysis, and interpretation of results. Maiko Kobayashi conducted data acquisition. Takashi Miura contributed to preparation of the experimental sites and cooperated with data acquisition. Takahide Kagawa and Qing Li participated in data acquisition and contributed to the interpretation of results. Shigeyoshi Kumeda and Michiko Imai conceived the study and participated in the interpretation of results. Yoshifumi Miyazaki conceived and designed the study and contributed to the interpretation of results and manuscript preparation. All authors have read and approved the final version submitted for publication.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Miyazaki, Y.; Ikei, H.; Song, C. Forest medicine research in Japan. *Jpn. J. Hyg.* **2014**, *69*, 123–135, (In Japanese). [CrossRef]
2. Lee, J.; Park, B.J.; Tsunetsugu, Y.; Kagawa, T.; Miyazaki, Y. The restorative effects of viewing real forest landscapes: Based on a comparison with urban landscapes. *Scand. J. Forest. Res.* **2009**, *24*, 227–234.
3. Tsunetsugu, Y.; Park, B.J.; Ishii, H.; Hirano, H.; Kagawa, T.; Miyazaki, Y. Physiological effects of "Shinrin-yoku" (taking in the atmosphere of the forest) in an old-growth broadleaf forest in Yamagata prefecture, Japan. *J. Physiol. Anthropol.* **2007**, *26*, 135–142. [CrossRef] [PubMed]
4. Park, B.J.; Tsunetsugu, Y.; Kasetani, T.; Kagawa, T.; Miyazaki, Y. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environ. Health. Prev. Med.* **2010**, *15*, 18–26. [PubMed]
5. Park, B.J.; Tsunetsugu, Y.; Lee, J.; Kagawa, T.; Miyazaki, Y. Effect of the forest environment on physiological relaxation using the results of field tests at 35 sites throughout Japan. In *Forest Medicine*; Li, Q., Ed.; Nova Science Publishers: New York, NY, USA, 2011; pp. 55–65.
6. Park, B.J.; Kasetani, T.; Morikawa, T.; Tsunetsugu, Y.; Kagawa, T.; Miyazaki, Y. Physiological effects of forest recreation in a young conifer forest in Hinokage Town, Japan. *Silva Fennica* **2009**, *43*, 291–301. [CrossRef]
7. Park, B.J.; Tsunetsugu, Y.; Ishii, H.; Furuhashi, S.; Hirano, H.; Kagawa, T.; Miyazaki, Y. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in a mixed forest in Shinano Town, Japan. *Scand. J. Forest. Res.* **2008**, *23*, 278–283. [CrossRef]
8. Lee, J.; Park, B.J.; Tsunetsugu, Y.; Ohira, T.; Kagawa, T.; Miyazaki, Y. Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. *Public Health* **2011**, *125*, 93–100. [CrossRef] [PubMed]
9. Lee, J.; Tsunetsugu, Y.; Takayama, N.; Park, B.J.; Li, Q.; Song, C.; Komatsu, M.; Ikei, H.; Tyrväinen, L.; Kagawa, T.; Miyazaki, Y. Influence of forest therapy on cardiovascular relaxation in young adults. *Evid. Based. Complement. Alternat. Med.* **2014**, *2014*. [CrossRef] [PubMed]
10. Tsunetsugu, Y.; Lee, J.; Park, B.J.; Tyrväinen, L.; Kagawa, T.; Miyazaki, Y. Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements. *Landsc. Urban Plan.* **2013**, *113*, 90–93.
11. Tsunetsugu, Y.; Park, B.J.; Miyazaki, Y. Trends in research related to "Shinrin-yoku" (taking in the forest atmosphere or forest bathing) in Japan. *Environ. Health. Prev. Med.* **2010**, *15*, 27–37. [CrossRef] [PubMed]

12. Park, B.J.; Tsunetsugu, Y.; Kasetani, T.; Hirano, H.; Kagawa, T.; Sato, M.; Miyazaki, Y. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest)—Using salivary cortisol and cerebral activity as indicators. *J. Physiol. Anthropol.* **2007**, *26*, 123–128. [CrossRef] [PubMed]
13. Bratman, G.N.; Hamilton, J.P.; Hahn, K.S.; Daily, G.C.; Gross, J.J. Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proc Natl Acad Sci USA* **2015**, *112*, 8567–8572. [CrossRef] [PubMed]
14. Li, Q.; Morimoto, K.; Nakadai, A.; Inagaki, H.; Katsumata, M.; Shimizu, T.; Hirata, Y.; Hirata, K.; Suzuki, H.; Miyazaki, Y.; *et al*. Forest bathing enhances human natural killer activity and expression of anti-cancer proteins. *Int. J. Immunopathol. Pharmacol.* **2007**, *20*, 3–8. [PubMed]
15. Li, Q.; Morimoto, K.; Kobayashi, M.; Inagaki, H.; Katsumata, M.; Hirata, Y.; Hirata, K.; Suzuki, H.; Li, Y.J.; Wakayama, Y.; *et al*. Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. *Int. J. Immunopathol. Pharmacol.* **2008**, *21*, 117–127. [PubMed]
16. Li, Q.; Morimoto, K.; Kobayashi, M.; Inagaki, H.; Katsumata, M.; Hirata, Y.; Hirata, K.; Shimizu, T.; Li, Y.J.; Wakayama, Y. A forest bathing trip increases human natural killer activity and expression of anti-cancer proteins in female subjects. *J. Biol. Regul. Homeost. Agents* **2008**, *22*, 45–55. [PubMed]
17. Li, Q.; Kobayashi, M.; Inagaki, H.; Hirata, Y.; Li, Y.J.; Hirata, K.; Shimizu, T.; Suzuki, H.; Katsumata, M.; Wakayama, Y.; *et al*. A day trip to a forest park increases human natural killer activity and the expression of anti-cancer proteins in male subjects. *J. Bio. Regul. Homeost.* **2010**, *24*, 157–165.
18. Takayama, N.; Korpela, K.; Lee, J.; Morikawa, T.; Tsunetsugu, Y.; Park, B.J.; Li, Q.; Tyrväinen, L.; Miyazaki, Y.; Kagawa, T. Emotional, restorative and vitalizing effects of forest and urban environments at four sites in Japan. *Int. J. Environ. Res. Public Health* **2014**, *11*, 7207–7230. [PubMed]
19. Park, B.J.; Furuya, K.; Kasetani, T.; Takayama, N.; Kagawa, T.; Miyazaki, Y. Relationship between psychological responses and physical environment in forest settings. *Landsc. Urban Plan.* **2011**, *102*, 24–32. [CrossRef]
20. Song, C.; Ikei, H.; Kobayashi, M.; Miura, T.; Taue, M.; Kagawa, T.; Li, Q.; Kumeda, S.; Imai, M.; Miyazaki, Y. Effect of forest walking on autonomic nervous system activity in middle-aged hypertensive individuals. *Int. J. Environ. Res. Public Health* **2015**, *12*, 2687–2699. [CrossRef] [PubMed]
21. Ochiai, H.; Ikei, H.; Song, C.; Kobayashi, M.; Takamatsu, A.; Miura, T.; Taue, M.; Kagawa, T.; Li, Q.; Kumeda, S.; *et al*. Physiological and psychological effects of forest therapy on middle-age males with high-normal blood pressure. *Int. J. Environ. Res. Public Health* **2015**, *12*, 2532–2542. [CrossRef] [PubMed]
22. NHLBI Obesity Education Initiative. *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults*; NHLBI Obesity Education Initiative Expert Panel on the Identification, Evaluation, and Treatment of Obesity in Adults (US) National Heart, Lung, and Blood Institute: Baltimore, MD, USA, 1998; p. 228.
23. World Health Organization. *Obesity: Preventing and Managing the Global Epidemic*; World Health Organization: Geneva, Switzerland, 2000; p. 265.
24. World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *JAMA* **2013**, *310*, 2191–2194.
25. Osgood, C.E.; Suchi, G.J.; Tannenbaum, P. *The Measurement of Meaning*; University of Illinois Press: Urbana, IL, USA, 1957.
26. McNair, D.M.; Lorr, M.; Droppleman, L. *Profile of Mood States Manual*; Educational and Industrial Testing Service: San Diego, CA, USA, 1992.
27. Frankenhauser, M. Experimental approach to the study of catecholamines and emotion. In *Emotions, Their Parameters and Measurement*; Levi, L., Ed.; Raven Press: New York, NY, USA, 1975; p. 209.
28. Kirschbaum, C.; Hellhammer, D.H. Salivary cortisol in psychoneuroendocrine research: Recent developments and applications. *Psychoneuroendocrinology* **1994**, *19*, 313–333. [CrossRef]
29. Poll, E.M.; Kreitschmann-Andermahr, I.; Langejuergen, Y.; Stanzel, S.; Gilsbach, J.M.; Gressner, A.; Yagmur, E. Saliva collection method affects predictability of serum cortisol. *Clin. Chim. Acta.* **2007**, *382*, 15–19. [CrossRef] [PubMed]
30. Ferguson, D.B. *Oral Bioscience*; Churchill Livingstone: London, UK, 1999; p. 136.
31. Kiernan, M.; Winkleby, M.A. Identifying patients for weight-loss treatment: An empirical evaluation of the NHLBI obesity education initiative expert panel treatment recommendations. *Arch. Intern. Med.* **2000**, *160*, 2169–2176. [CrossRef] [PubMed]

32. Song, C.; Ikei, H.; Miyazaki, Y. Elucidation of a physiological adjustment effect in a forest environment: A pilot study. *Int. J. Environ. Res. Public Health* **2015**, *12*, 4247–4255. [CrossRef] [PubMed]
33. Duchesne, A.; Pruessner, J.C. Association between subjective and cortisol stress response depends on the menstrual cycle phase. *Psychoneuroendocrinology* **2013**, *38*, 3155–3159. [CrossRef] [PubMed]
34. Watanabe, K.; Shirakawa, T. Characteristics of perceived stress and salivary levels of secretory immunoglobulin A and cortisol in Japanese women with premenstrual syndrome. *Nurs. Midwifery Stud.* **2015**, *4*. [CrossRef] [PubMed]
35. Evans, J.M.; Ziegler, M.G.; Patwardhan, A.R.; Ott, J.B.; Kim, C.S.; Leonelli, F.M.; Knapp, C.F. Gender differences in autonomic cardiovascular regulation: Spectral, hormonal, and hemodynamic indexes. *J. Appl. Physiol.* **2001**, *91*, 2611–2618. [PubMed]
36. Earnest, C.P.; Lavie, C.J.; Blair, S.N.; Church, T.S. Heart rate variability characteristics in sedentary postmenopausal women following six months of exercise training: The DREW study. *PLoS ONE* **2008**, *3*. [CrossRef] [PubMed]

平成27年度
森林浴による健康増進等に関する調査研究
報告書

平成28年3月

日本医科大学衛生学公衆衛生学
李　卿

目次

1.はじめに

森林環境は、その静かな雰囲気、美しい景観、穏やかな気候、清浄な空気及び特有な香りなどの要素で古くから人々に好まれている。森林浴は、五感（視覚・嗅覚・聴覚・触覚・味覚）を刺激してその効果を発揮する。最近では森林散策を通して森林の持つ癒し効果を人々の健康増進・疾病予防に活用する傾向が強くなってきている。

これまでの研究では、森林セラピーが以下の生理的・心理的効果を生み出していることが実証されている。

① NK(natural killer)活性を指標とした免疫機能の改善、
② NK細胞数の増加、
③ NK細胞内抗がんタンパク質の増加、
④ ストレスホルモン濃度の低下、
⑤ リラックス状態で高まる副交感神経活動の昂進、
⑥ ストレス状態で高まる交感神経活動の抑制、
⑦ 収縮期・拡張期血圧、脈拍数の低下、
⑧ POMS(The profile of mood states)調査において「活気」の得点が有意に上昇し、「緊張・不安」、「抑うつ」、「敵意・怒り」、「混乱」、「疲労」の得点が有意に低下し、「うつ状態」の改善に有効であること。

一方、日本において、2011年の高血圧症患者数は、906.7万人で傷病別の1位を占める。2012年では心疾患による死亡は、全死亡の15.8%（2位）、脳血管疾患による死亡は、全死亡の9.7%（4位）、両者を合わせると全死亡の25.5%を占める。心疾患も脳血管疾患もその発症において高血圧が共通のリスクファクターである。また国民の疾病別の通院者率は、男女とも高血圧症が1位である。さらに傷病別の国民医療費は、高血圧症を含む循環器系疾患が1位を占める。このように高血圧症の予防は国民の健康増進においても生活習慣病予防においてもさらに国民医療費削減においてもその重要性は一目瞭然である。

森林浴による高血圧症患者の血圧降下作用は国民の健康増進、生活習慣病予防及び国民医療費削減に十分に貢献できると予想される。

以上の背景を踏まえて平成25と26年度では、中高年男性と女性の方々を被験者として、データ蓄積を行ったが、森林散策の間に血圧測定のポイント数が少なく、森林浴の血圧降下効果を確定するためにはさらなるデータの蓄積が必要となり、特に森林滞在中に頻繁に定時的に血圧を測定する研究は必要不可欠である。そのため、平成27年度では、男性の境界域高血圧の方々を被験者として携帯型血圧計を用いて森林滞在中に定時的に血圧を測定し、より多い血圧データを取得することにした。さらに森林浴による心血管系及び糖脂質代謝系などへの影響についても検討することにした。

2.森林浴による血圧や心拍数など心血管系及び糖脂質代謝などへの影響

（1）実験対象者と実験方法

1）被験者情報

本研究の対象者は、高血圧症以外の心血管疾患の現病・既往歴を有さず、生活習慣病関連の内服治療を受けていない境界域高血圧または高血圧症の男性 19 名である。被験者の収縮期の平均血圧は 144.0±9.0 mmHg であり、拡張期の平均血圧は 92.6±7.4 mmHg である。被験者の詳細な情報は表 1 に示されている。

表 1　被験者情報（男性）

番号	年齢	身長 (cm)	体重 (kg)	BMI	喫煙状況	収縮期血圧（mmHg）	拡張期血圧（mmHg）	備考#	脈拍（拍/分）
1	69	168	57	20	×	142	83	I 度 HT	63
2	67	179	72	22	×	138	85	正常高値	60
3	40	184	87	26	○	127	81	正常	92
4	56	176	62	20	×	148	84	I 度 HT	101
5	44	166	74	29	×	144	93	I 度 HT	73
6	46	180	68	21	○	143	92	I 度 HT	79
7	55	167	54	19	×	157	103	II 度 HT	81
8	49	173	65	22	×	150	99	I 度 HT	62
9	40	179	84	26	×	146	99	I 度 HT	68
10	44	172	74	25	○	148	92	I 度 HT	80
11	46	184	70	21	○	143	84	I 度 HT	96
12	46	165	58	21	×	147	98	I 度 HT	70
13	49	172	78	26	×	149	104	I 度 HT	79
14	66	172	70	23	×	161	95	II 度 HT	61
15	50	170	63	22	○	155	106	II 度 HT	64
16	44	170	102	35	×	131	93	I 度 HT	75
18	45	165	61	22	×	141	84	I 度 HT	60
19	59	176	70	23	×	140	90	I 度 HT	64
20	58	182	85	26	×	126	94	I 度 HT	67
平均	51.2	173.7	71.2	23.7		144.0	92.6		73.4
標準偏差	8.8	6.1	11.7	3.7		9.0	7.4		12.1
標準誤差	2.0	1.4	2.7	0.9		2.1	1.7		2.8

17 番は途中から退出、血圧と脈拍は面接時の測定値、#: 日本高血圧学会「高血圧治療ガイドライン 2014」に基づいた(Shimamoto　et al. 2014)。HT：高血圧

日本高血圧学会「高血圧治療ガイドライン 2014」

分類	収縮期血圧（mmHg）		拡張期血圧（mmHg）
至適血圧	<120	かつ	<80
正常血圧	120～129	かつ/または	80～84
正常高値血圧	130～139	かつ/または	85～89
I 度高血圧	140～159	かつ/または	90～99
II 度高血圧	160～179	かつ/または	100～109
III 度高血圧	≧180	かつ/または	≧110
収縮期高血圧	≧ 140	かつ	<90

2）実験フィールド

森林セラピー用の実験地は、赤沢自然休養林とし、比較のための対照地は長野県伊那市とした。

3）測定指標及び測定方法

①携帯型血圧計による収縮期血圧の定時測定
②携帯型血圧計による拡張期血圧の定時測定
③携帯型血圧計による脈拍数の定時測定
④ストレスホルモンの計測：尿中アドレナリン、ノルアドレナリン、ドーパミン及びコルチゾール濃度等
⑤血液指標（脂質、糖代謝等の指標）：血中アディポネクチン、DHEA-S (dehydroepiandrosterone sulfate)、中性脂肪、総コレステロール、LDL-コレステロール、HDL-コレステロール、空腹血糖値、インスリン濃度、高感度 CRP、白血球数・分画、赤血球数及びヘモグロビン濃度など
⑥POMS と自覚症状（日本産業衛生学会疲労研究会）に関するアンケート調査
⑦環境温度、湿度、気圧の計測

4）森林散策及び都市散策

森林浴による持続効果の影響を避けるために都市部散策実験を先に実施し、1 週間後に森林散策実験を実施した。都市部散策は 8 月に長野県伊那市にて実施し、その 1 週間後に森林散策実験を実施した。また 9 月末に都市部散策実験を追加した。散策時間は午前（11：00～12：20）と午後（13：40～15：00）それぞれ 80 分であり、散策距離は、午前と午後それぞれ 2.6ｋｍであり、散策途中それぞれ 15 分の休憩を取った（写真 1-4)。都市散策と森林散策において散策距離、散策速度、散策時間及び散策時刻はいずれも同じであった。採血

は各散策日朝食前及び散策後翌日朝食前に実施した。収縮期・拡張期血圧及び脈拍は、20分間隔で携帯型自動血圧計を用いて計測した。喫煙の影響を排除するために喫煙者は散策中に禁煙であった。カフェインの影響を排除するために散策前後及び散策中は全員にミネラルウオーターを提供した。食事の影響を排除するために散策日に全員に同じ朝食と昼食を提供した。

本研究は日本医科大学及び長野県立木曽病院の倫理委員会にてそれぞれ承認され、本研究の実施に当たっては、全ての被験者から文書でインフォームド・コンセントの手続きを取った。

写真 1.　都市部散策の風景（午前）

写真 2.　都市部散策の風景（午後）

写真 3.　森林散策の風景(午前)

写真4.　森林散策の風景（午後）

（2）結果と考察

1）散策中環境温度、湿度及び気圧

散策中環境温度、湿度、気圧の測定結果は図1-3及び表2-4に示されている。

都市散策時の気象状況は、晴れ、午前、最高気温32.7℃、平均気温31.2±0.7℃、平均湿度52.4±2.6％、午後、晴れ、最高気温37.5℃、平均気温33.2±1.4℃、平均湿度47.5±4.3％であった。森林散策は都市散策の1週間後に長野県上松町の赤沢自然休養林にて実施した。森林散策時の気象状況は、午前、雨、最高気温20.4℃、平均気温19.1±0.5℃、平均湿度94.3±3.9％、午後、曇り時々雨、最高気温20.7℃、平均気温19.4±0.4℃、平均湿度90.5±4.2％であった。

図1.　都市部（8月22日）と森林（8月29日）散策中の環境気温

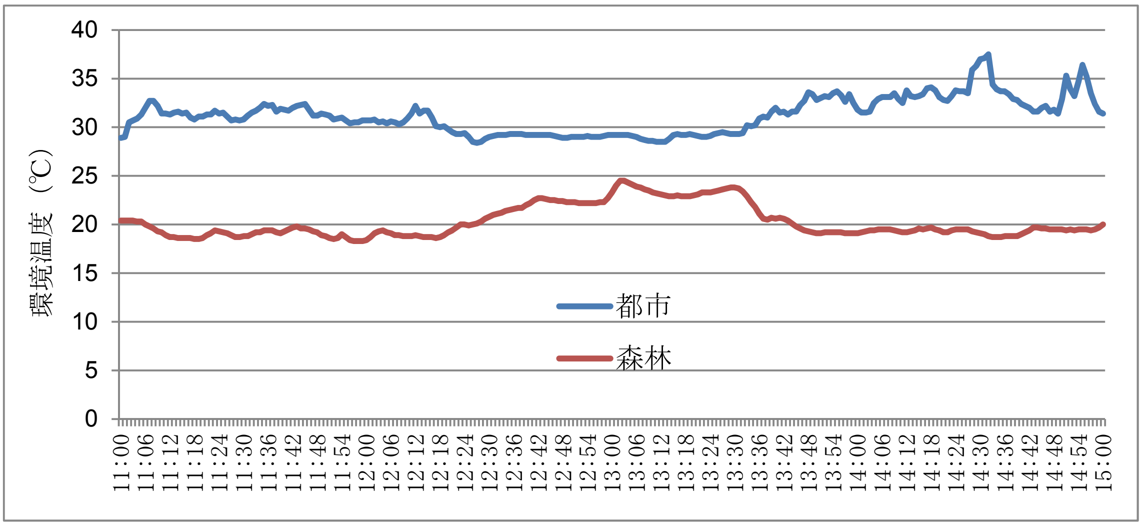


表2.　都市部散策中の環境気温、湿度及び気圧（8月22日）

都市平均 (11:00-12:20)			
	温度（゜C）	湿度（%）	気圧（hPa）
平均	31.2	52.4	930.6
標準偏差	0.7	2.6	0.3
標準誤差	0.1	0.3	0.0
測定数	81	81	81
最大値	32.7	59	931.2

都市平均 (13:40-15:00)			
	温度（゜C）	湿度（%）	気圧（hPa）
平均	33.2	47.5	929.6
標準偏差	1.4	4.3	0.4
標準誤差	0.2	0.5	0.0
測定数	81	81	81
最大値	37.5	56	930.2

表3.　森林散策中の環境気温、湿度及び気圧（8月29日）

森林内平均 (11:00-12:20)			
	温度（゜C）	湿度（%）	気圧（hPa）
平均	19.1	94.3	886.9
標準偏差	0.5	3.9	1.2
標準誤差	0.1	0.4	0.1
測定数	81	81	81
最大値	20.4	98.0	888.8

森林内平均 (13:40-15:00)			
	温度（゜C）	湿度（%）	気圧（hPa）
平均	19.4	90.5	886.5
標準偏差	0.4	4.2	1.1
標準誤差	0.0	0.5	0.1
測定数	81	81	81
最大値	20.7	98.0	888.3

都市部における追加実験散策時の気象状況は、午前、晴れ、最高気温27.3℃、平均気温25.0±0.9℃、平均湿度59.2±3.4%、午後、晴れ、最高気温28.4℃、平均気温26.5±0.6℃、平均湿度56.5±2.3%であった（図3、表4）。

図2.　都市部(9月26日)と森林(8月29日)散策中の環境気温

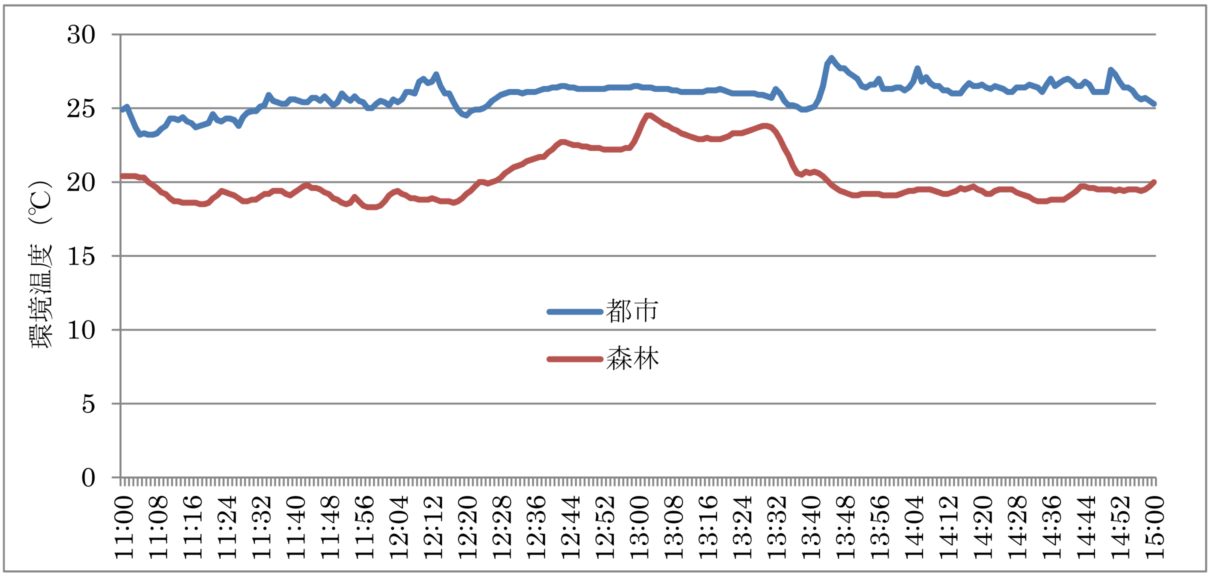


図3.　都市部(8月22日、9月26日)と森林(8月29日)散策中の環境気温

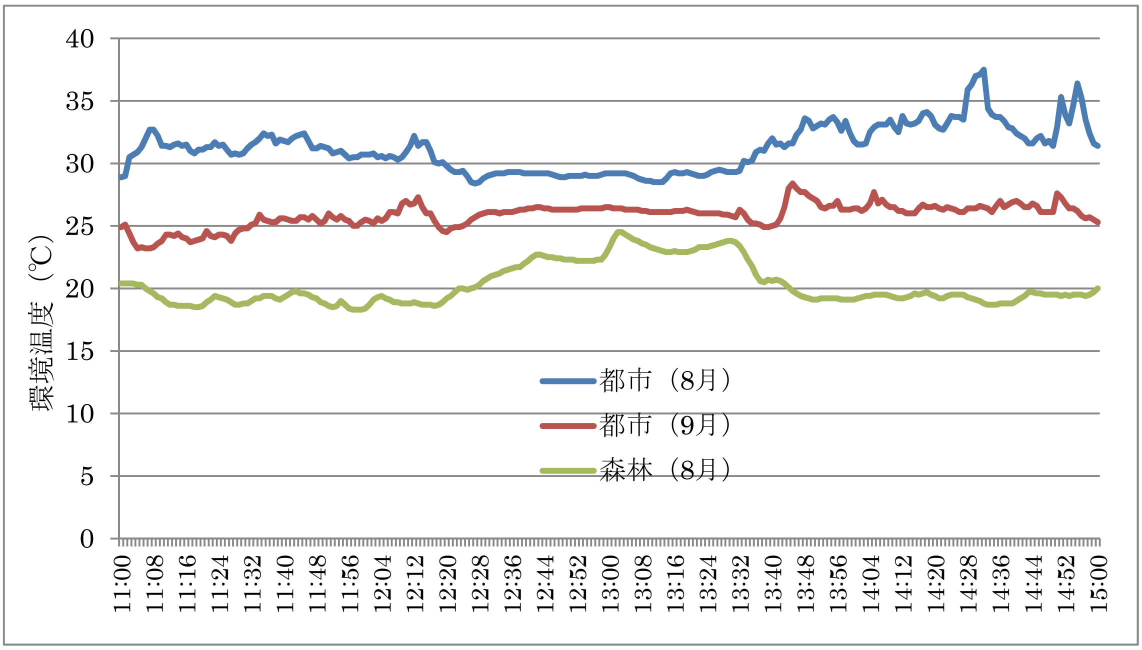


表4.　都市散策中の環境気温、湿度及び気圧（9月26日）

都市平均 (11:00-12:20)			
	° C	%RH	hPa
平均値	25.0	59.2	935.8
標準偏差	0.9	3.4	0.5
標準誤差	0.1	0.4	0.1
測定数	81	81	81
最大値	27.3	66	936.4

都市平均 (13:40-15:00)			
	° C	%RH	hPa
平均値	26.5	56.5	935.1
標準偏差	0.6	2.3	0.4
標準誤差	0.1	0.3	0.0
測定数	81	81	81
最大値	28.4	60	935.5

2）森林浴による血圧への影響

収取期血圧（図4、5）と拡張期血圧（図6、7）においていずれも森林散策中と都市散策中との間に統計的な有意差が認められなかった。また散策前後においても都市部と森林部との間に統計的な有意差が認められなかった。文献検索の結果、気温が血圧に大きな影響を与え、気温が高くなると血圧が低下するが、一方で気温が低くなると血圧が上昇すると報告されている(Woodhouse et al. 1993, Jansen et al. 2001, Hozawa et al. 2011, Zhang et al. 2014)。さらにWoodhouseら（1993）は一定の範囲において気温と血圧との間に逆の相関を示し、気

温1℃低下すると、収縮血圧が1.3 mmHg 、拡張期血圧が0.6 mmHg それぞれ上昇すると報告している。Hozawaらも外気温10-23.9℃の間に気温と血圧との間に逆の相関を示し、気温1℃低下すると、収縮血圧が0.4 mmHg 、拡張期血圧が0.28 mmHg それぞれ上昇すると報告している。本実験において都市散策時の気象状況は、午前、最高気温32.7℃、平均気温31.2±0.7℃、平均湿度52.4±2.6%、午後、最高気温37.5℃、平均気温33.2±1.4℃、平均湿度47.5±4.3%である。一方、森林散策時の気象状況は、午前、最高気温20.4℃、平均気温19.1±0.5℃、平均湿度94.3±3.9%、午後、最高気温20.7℃、平均気温19.4±0.4℃、平均湿度90.5±4.2%である。都市散策時の平均気温が森林散策時より12.1-13.8℃も高く、最高気温の差は16.8℃もあった。また都市部における追加実験散策時の気象状況は、午前、最高気温27.3℃、平均気温25.0±0.9℃、平均湿度59.2±3.4%、午後、最高気温28.4℃、平均気温26.5±0.6℃、平均湿度56.5±2.3%である。いずれも森林環境より遥かに高温であった。本来ならば低気温環境下で血圧が上昇するはずであるが、本研究では森林散策時に低気温にもかかわらず、その血圧が都市散策時（高気温環境）の血圧とほぼ同じレベルであった。これは森林環境が低気温による血圧の上昇を阻止したと示唆された。言い換えれば、森林浴による血圧降下作用が低気温による血圧上昇作用に抹消されたと考えられる。この視点から考えれば、本研究では森林浴による血圧降下作用があったが、気温差の影響で森林浴の効果が隠されたと考えられる。

図4.　8月散策中収縮期血圧(n=19)

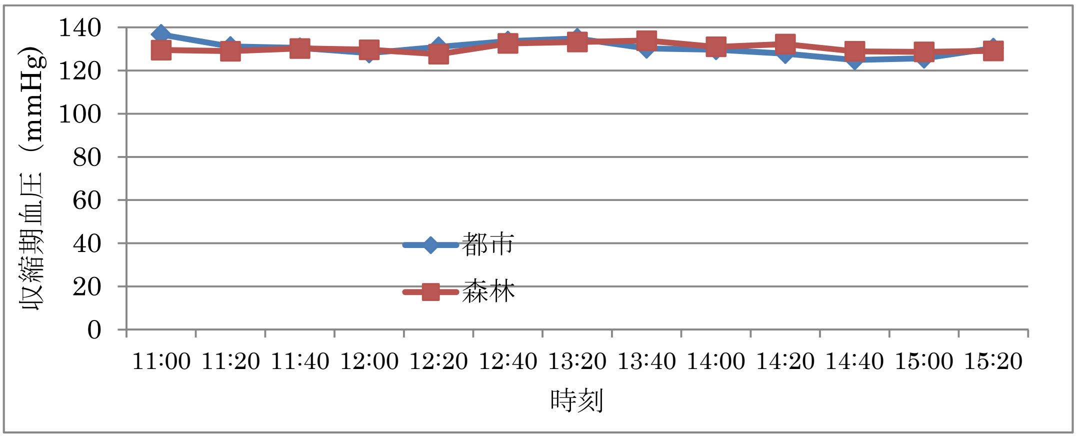


図 5.　9 月散策中収縮期血圧(n=12)

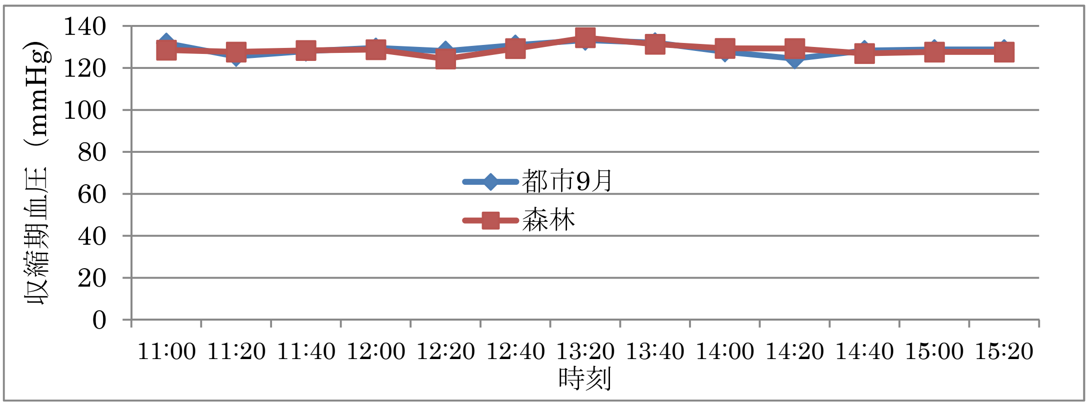


図6.　8月散策中拡張期血圧(n=19)

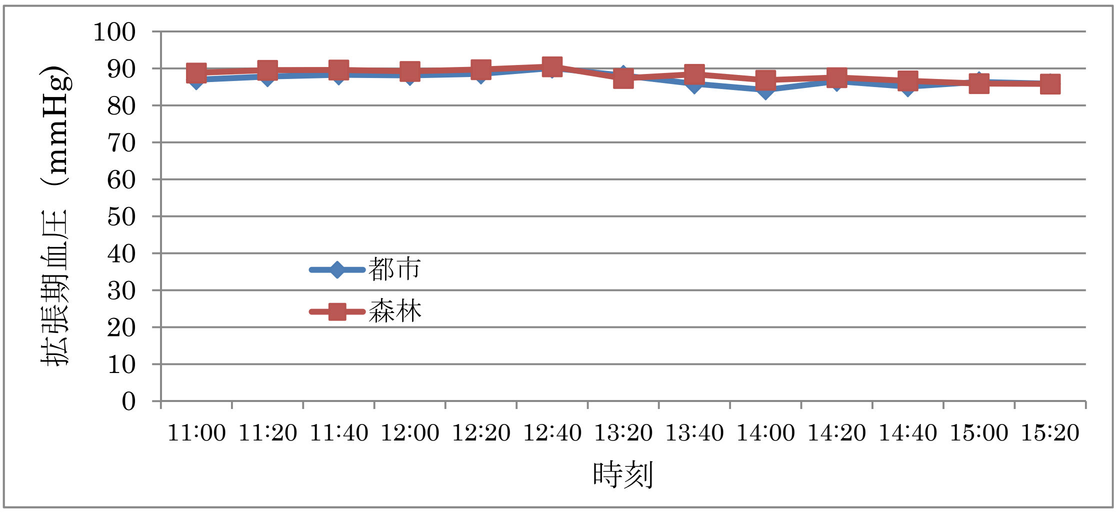
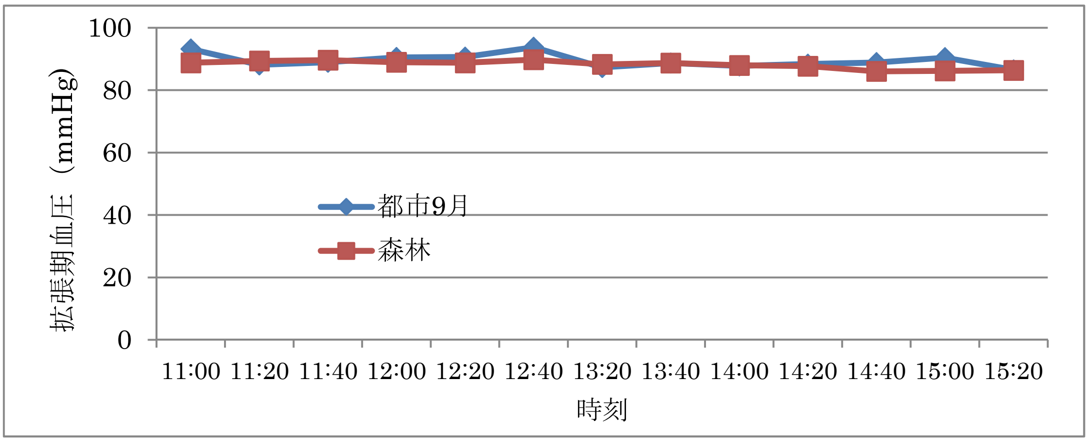


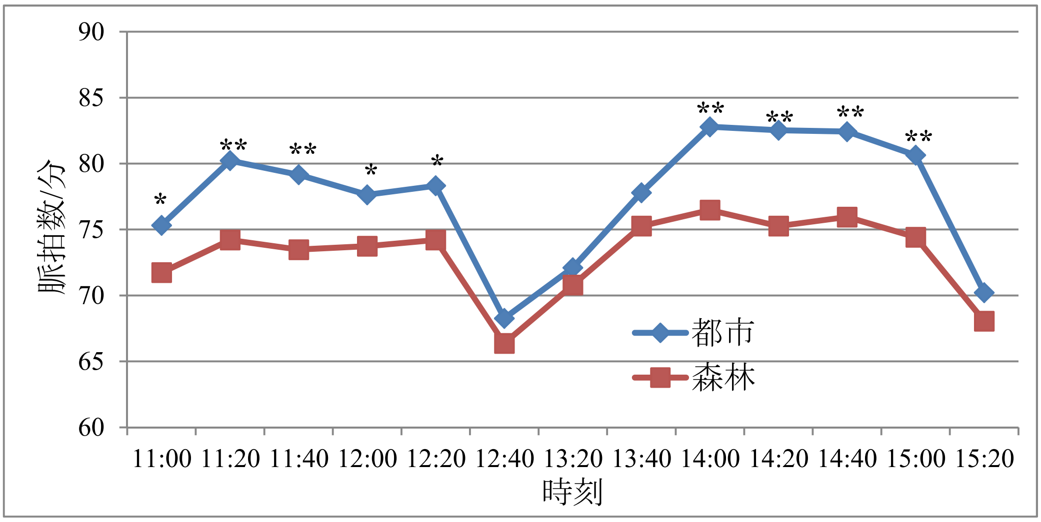
図 7.　9 月散策中拡張期血圧(n=12)



3）森林浴による脈拍数への影響

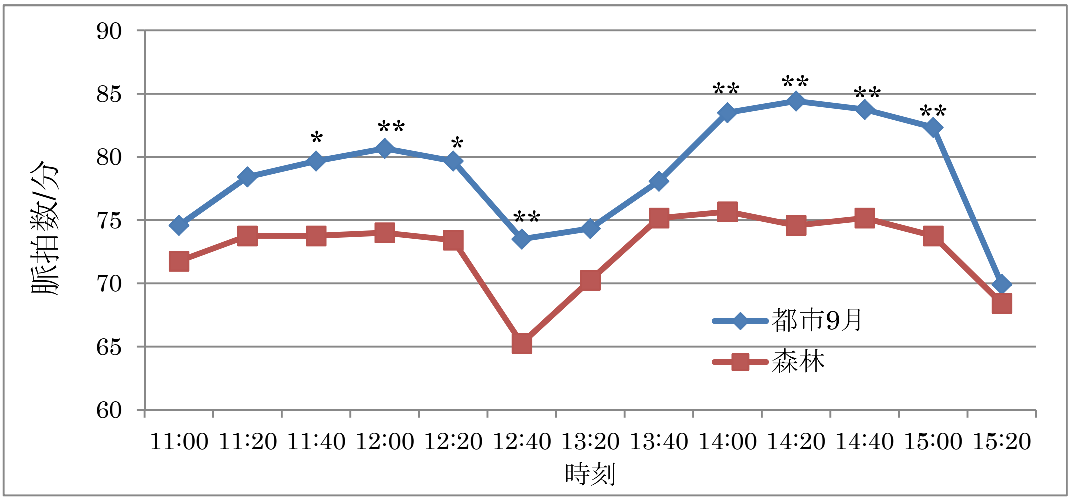
一方、森林散策中（11：00～12：20、14：00～15：00）の脈拍は都市散策と比較して有意に低下することが認められた（図 8、9）。これは平成 25 と 26 年度の結果を再現した。

図 8.　8 月散策中脈拍数



*: p<0.05, **: p<0.01 森林との比較（n=19）、対応のある t 検定（両側）

図 9.　9 月散策中脈拍数



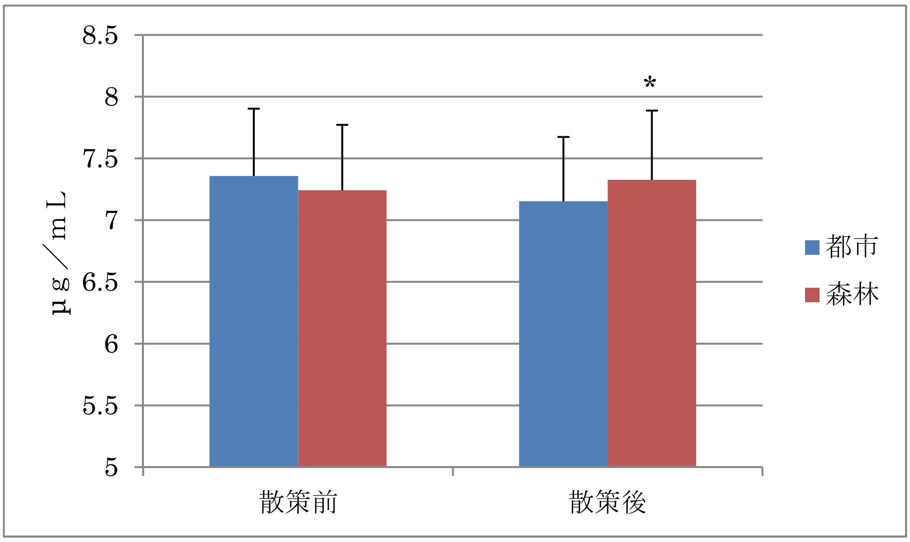
*: p<0.05, **: p<0.01 森林との比較(n=12)、対応のある t 検定（両側）

追加実験においても森林散策中（11：40～12：40、14：00～15：00）の脈拍は都市散策と比較して有意に低下することが認められ、8 月および平成 25 と 26 年度の実験結果を再現した。

4）森林浴による血中アディポネクチン濃度への影響

アデイポネクチンは脂肪組織より分泌されたホルモンで、動脈硬化予防効果やアンチエージング効果が報告されている。散策前、血中アディポネクチン濃度（ベースライン）に有意差はなかったが、一方、森林散策後が都市散策後より有意に高いことが認められ、森林散策が血中アディポネクチンの変化に良い影響を与えたことが示唆された（図 10）。

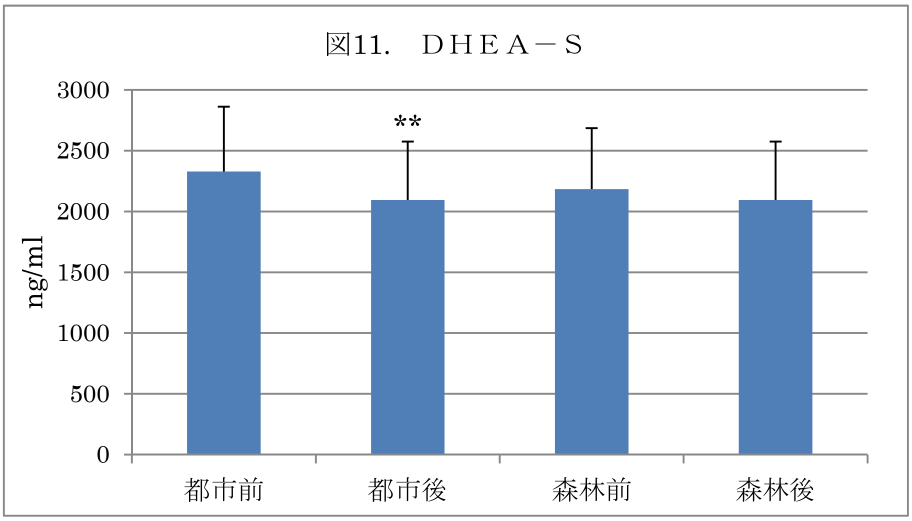
図 10.　血中アディポネクチン濃度



*: p<0.05, 都市との比較、対応のある t 検定（両側） (平均値+標準誤差、n=19)

5）森林浴による血中 DHEA-S 濃度への影響

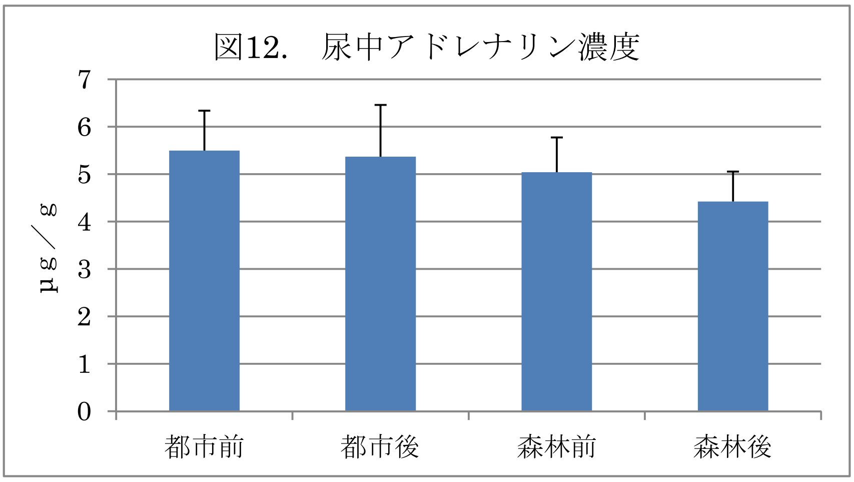
DHEA-S は主に副腎から分泌されるステロイドホルモンで、血中 DHEA-S のレベルは加齢に伴い、急激に減少するが、DHEA と DHEA-S による心疾患、肥満及び糖尿病の予防効果が報告され、アンチエージング指標として注目されている。都市散策後に血中 DHEA-S 濃度が有意に低下したが、森林散策による影響は認められなかった（図 11)。



p<0.01, 都市前との比較(平均値+標準誤差、n=19) 、対応のある t 検定（両側）

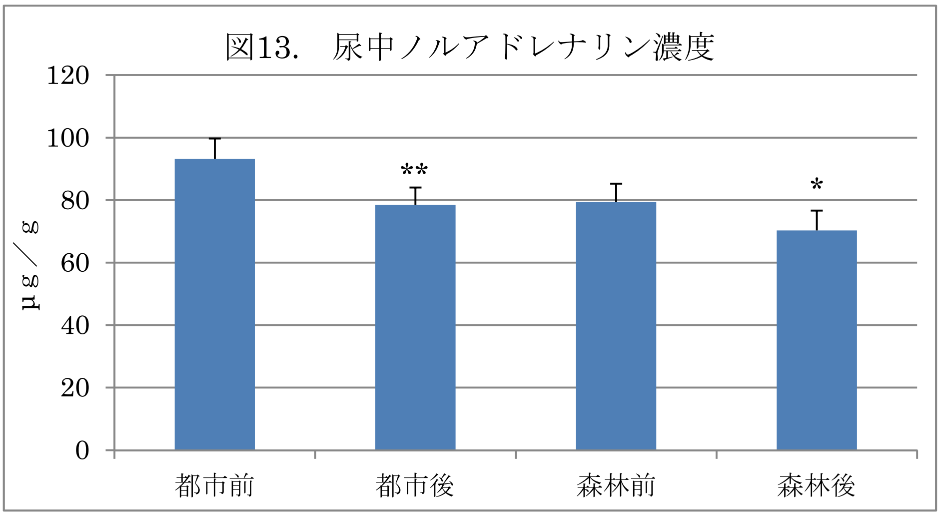
6）森林浴による尿中ストレスホルモンへの影響

森林散策後、尿中アドレナリン濃度が低下傾向を示したが、有意差が認められなかった（図12）。



平均値+標準誤差、n=19、対応のある t 検定（両側）

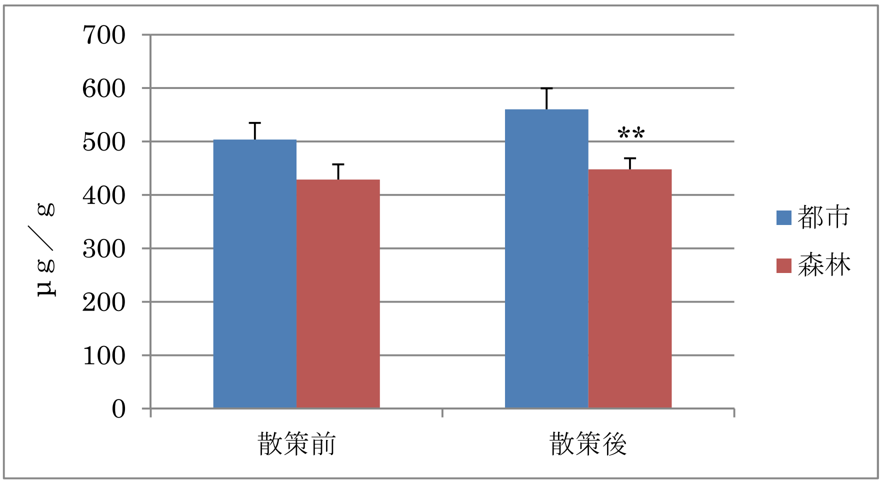
森林と都市散策後、尿中ノルアドレナリン濃度が共に有意に低下した（図 13）。



**: p<0.01, *: p<0.05, 各散策前との比較
(平均値+標準誤差、n=19) 、対応のある t 検定（両側）

散策前、尿中ドーパミン濃度（ベースライン）に有意差はなかったが、一方、森林散策後が都市散策後よりも有意に低下することが認められ、森林散策が尿中ドーパミンの変化に良い影響を与えたことが示唆された（図 14)。

図 14.　尿中ドーパミン濃度



**: p<0.01, 都市との比較(平均値+標準誤差、n=19) 、対応のある t 検定（両側）

都市散策後、尿中コルチゾール濃度が有意に上昇した。一方、森林散策後に低下傾向を示したが、有意差は認められなかった（図 15）。

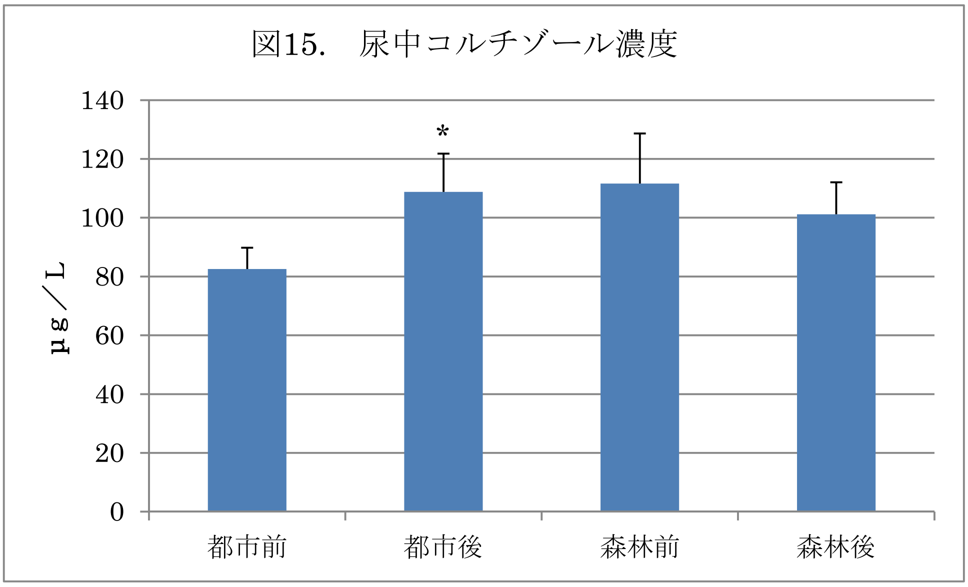
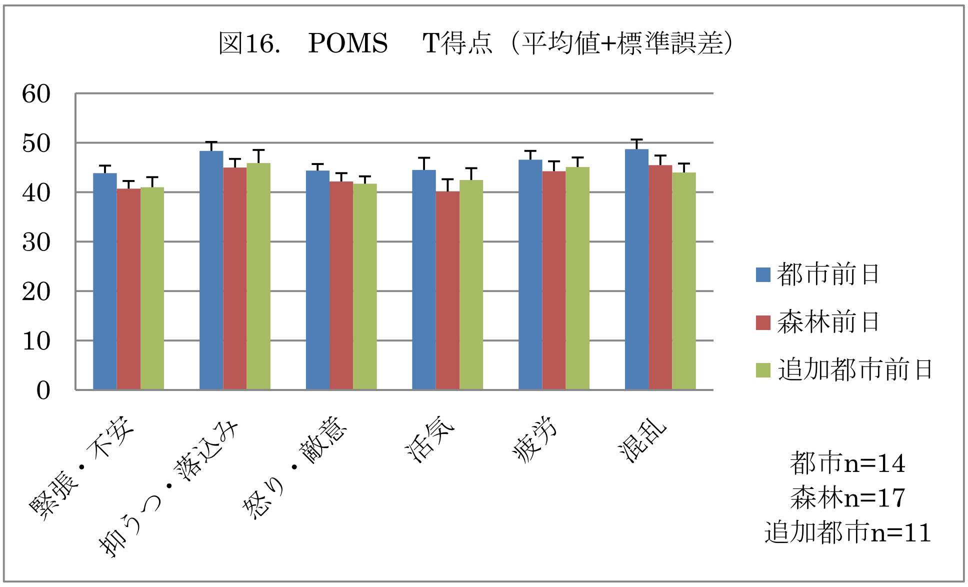


図15.　尿中コルチゾール濃度

*: p<0.05, 都市前との比較(平均値+標準誤差、n=19) 、対応のある t 検定（両側）

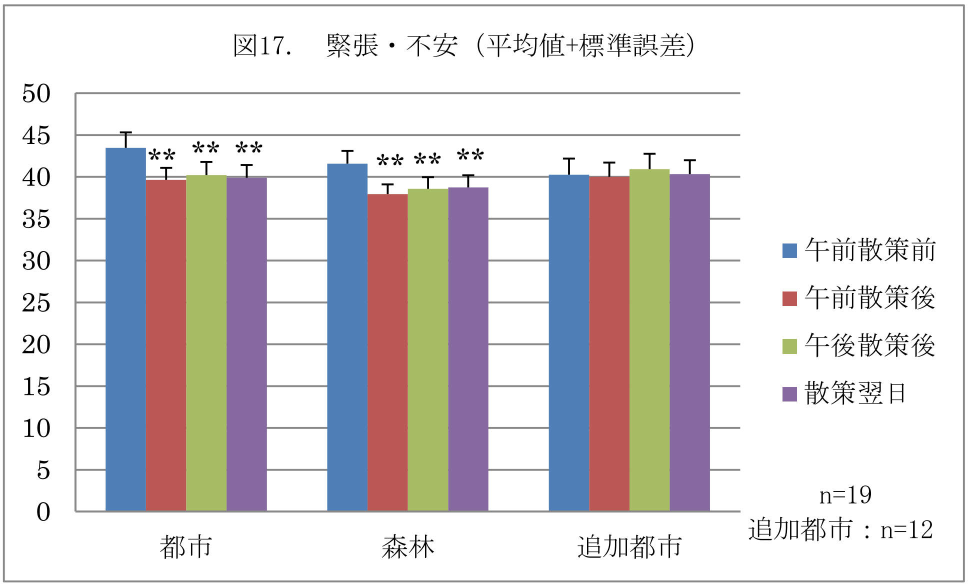
7）森林浴による POMS 得点への影響

POMS における各自覚症状の得点において都市散策前日と森林散策前日との間に統計的な有意差はなかった（図 16）。これは両散策前における被験者の状態には差異がなかったことを意味する。



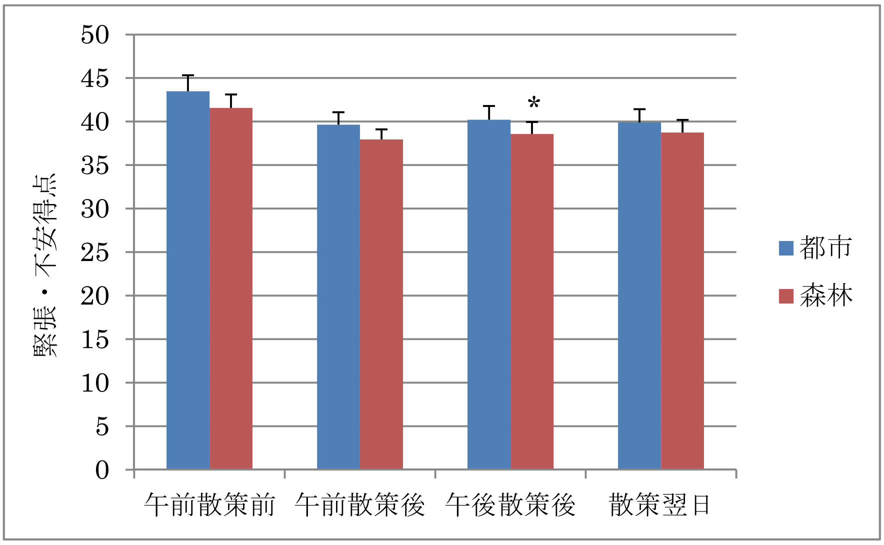
p>0.05 分散分析

緊張・不安の得点について都市と森林散策後のいずれも各散策前より有意に減少したことが明らかとなり、両散策による改善効果が認められた（図 17）。



* : p<0.05、** : p<0.01 午前散策前との比較、対応のある t 検定（両側）

図 18.　緊張・不安の結果

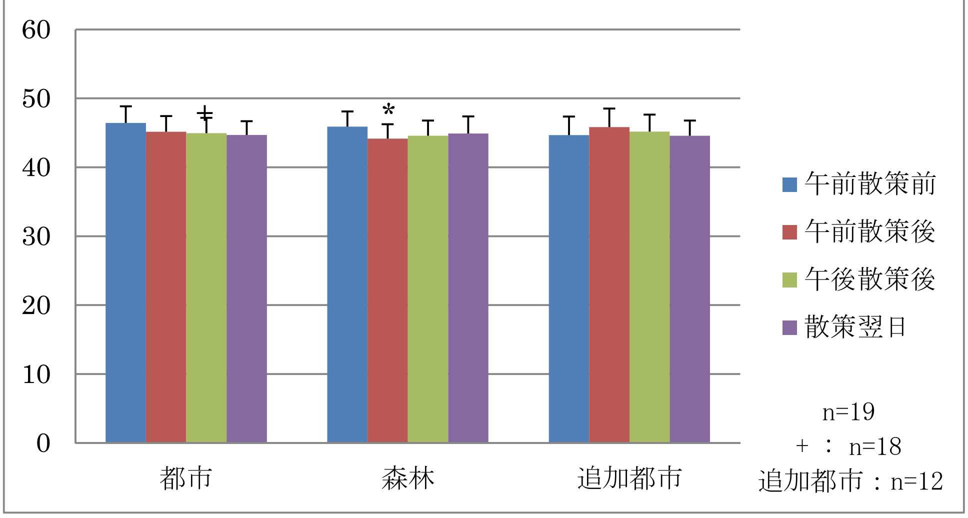


平均値+標準誤差、n=19、* : p<0.05、都市との比較、対応のある t 検定（両側）

さらに都市散策と比較して午後の森林散策後に有意に減少したことから、森林散策による効果が示唆された(図 18)。

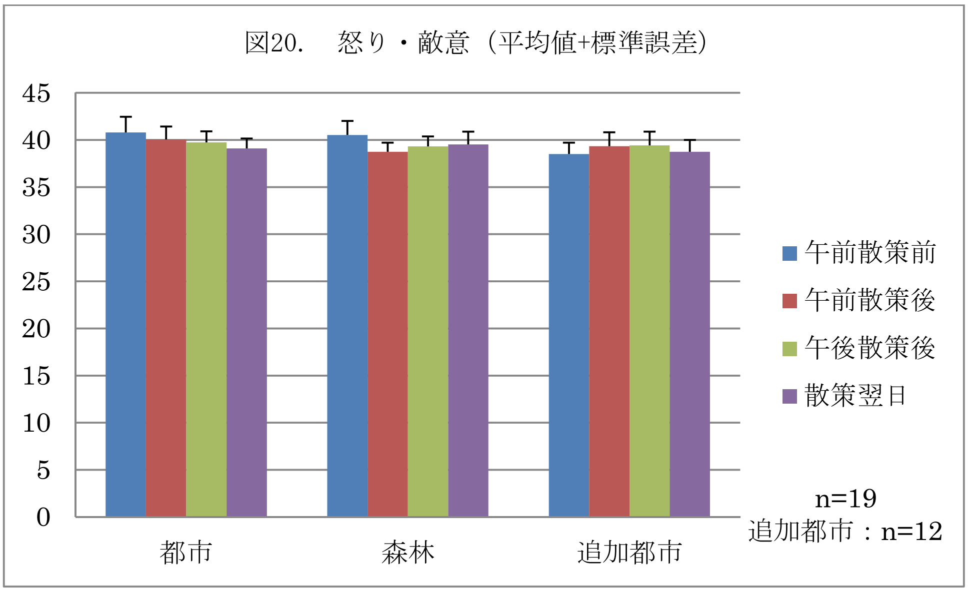
抑うつ・落ち込みの得点について午前の森林散策後に有意に減少したが、都市散後に有意な減少が認められなかったことから、森林散策による効果が示唆された（図 19）。

図19.　抑うつ・落込み



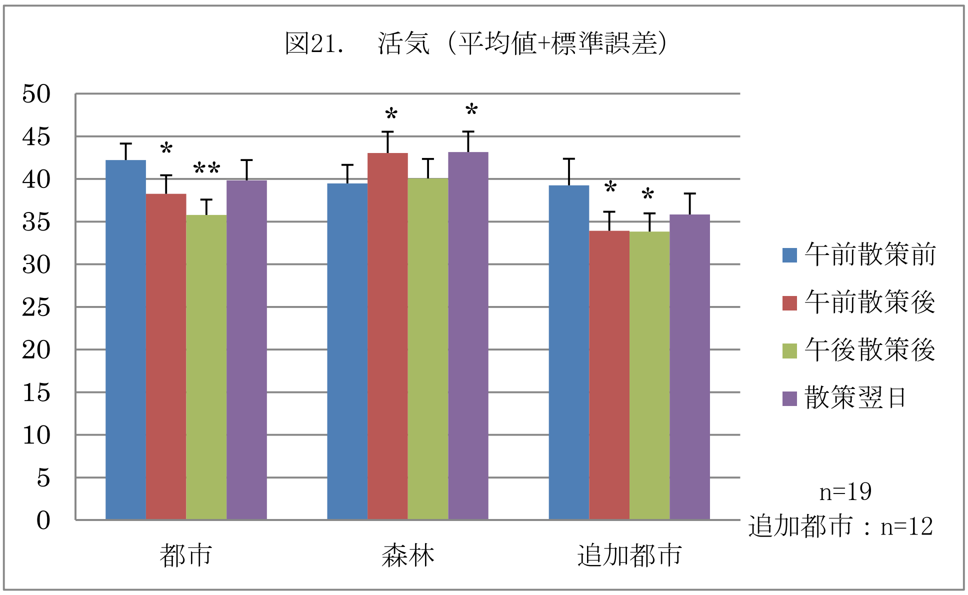
* : p<0.05 午前散策前との比較、対応のある t 検定及び等分散を仮定した２標本による t 検定（両側）

怒り・敵意の得点について両散策による影響が認められなかった（図 20）。



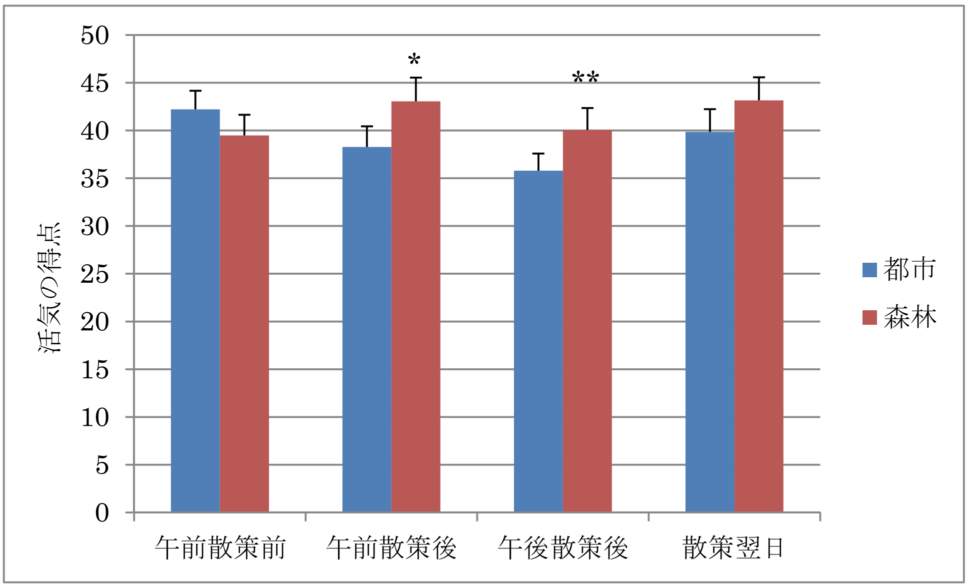
対応のある t 検定（両側）

活気の得点について午前の森林散策後及び散策翌日に有意に増加した。一方、午前と午後の都市散後に有意に減少した（図 21）。さらに図 22 に示されたように、都市散策と比較して午前と午後の森林散策後に有意に減少したことから、森林散策による活気上昇効果が示唆された。



* : p<0.05、** : p<0.01 午前散策前との比較、対応のある t 検定（両側）

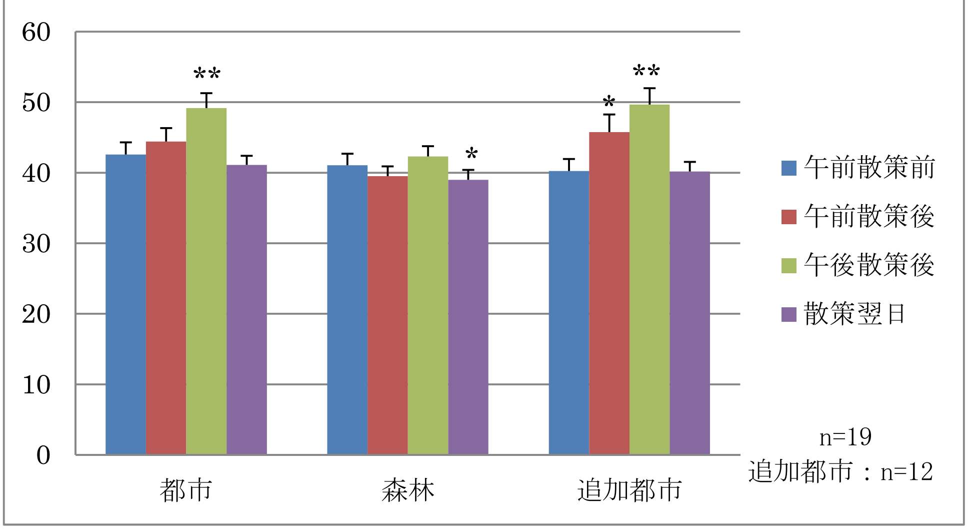
図 22.　活気の結果



平均値+標準誤差（n=19）、* : p<0.05、** : p<0.01 都市との比較、対応のある t 検定（両側）

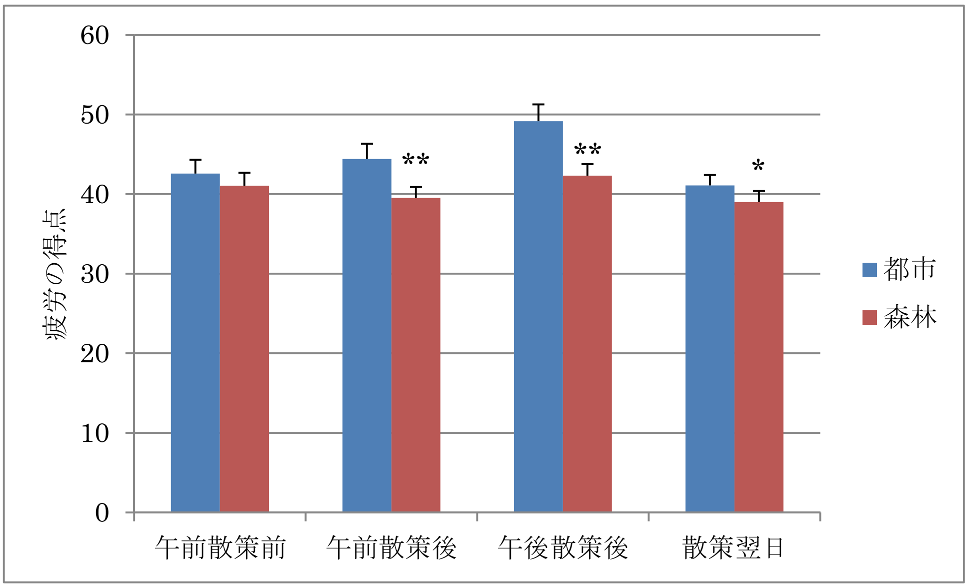
疲労の得点について森林散策翌日に有意に減少した。一方、午後の都市散後に有意に増加した（（図 23)。さらに図 24 に示されたように都市散策と比較して午前と午後の森林散策後及びの森林散策後翌日に有意に減少したことから、森林散策の疲労解消効果が示唆された。

図23.　疲労（平均値+標準誤差）



* : p<0.05、** : p<0.01 午前散策前との比較、対応のある t 検定（両側）

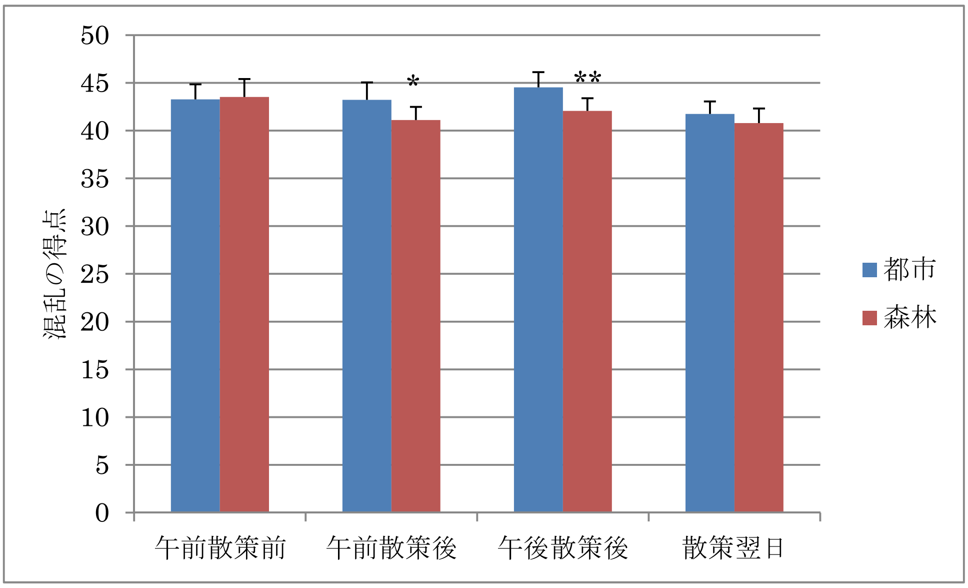
図 24.　疲労の結果



平均値+標準誤差（n=19）、* : p<0.05、** : p<0.01 都市との比較、対応のある t 検定（両側）

混乱の得点について都市散策と比較して午前と午後の森林散策後に有意に減少したことから、森林散策効果が示唆された（図 25）。

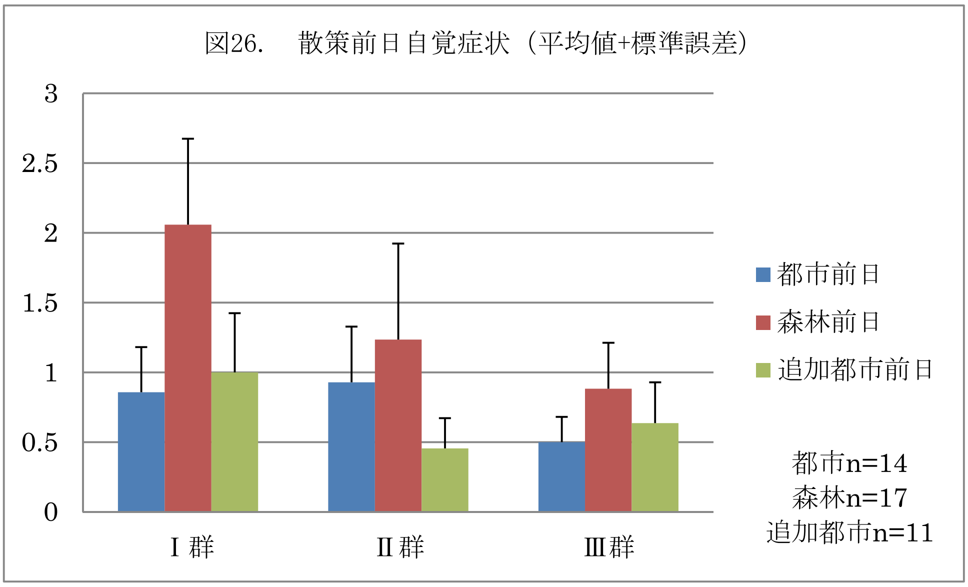
図 25.　混乱の結果



平均値+標準誤差、n=19、* : p<0.05、** : p<0.01 都市との比較、対応のある t 検定（両側）

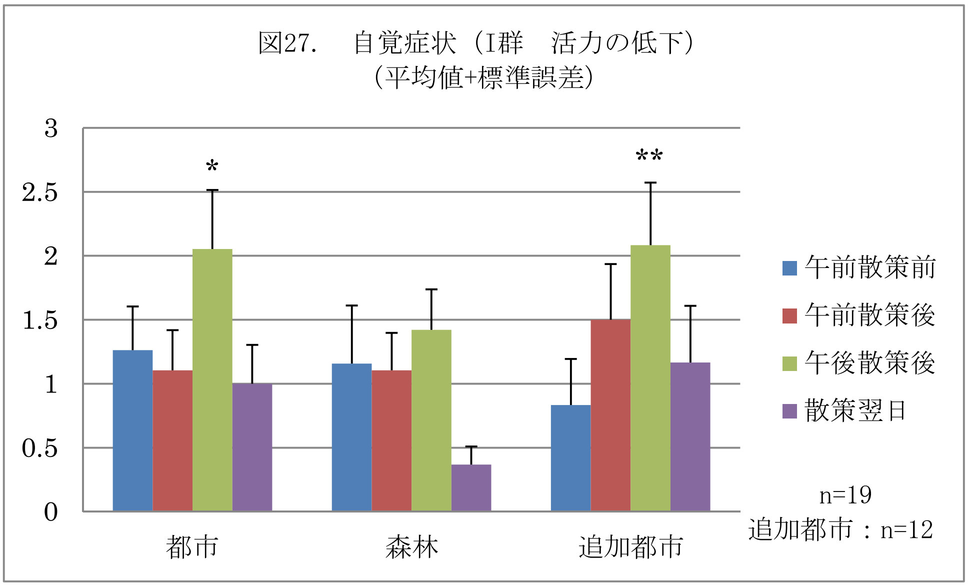
8）森林浴による疲労自覚症状への影響

各自覚症状の得点において都市散策前日と森林散策前日との間に統計的な有意差はなかった。これは両散策前における被験者の状態には差異がなかったことを意味する（図 26）。



p>0.05 分散分析

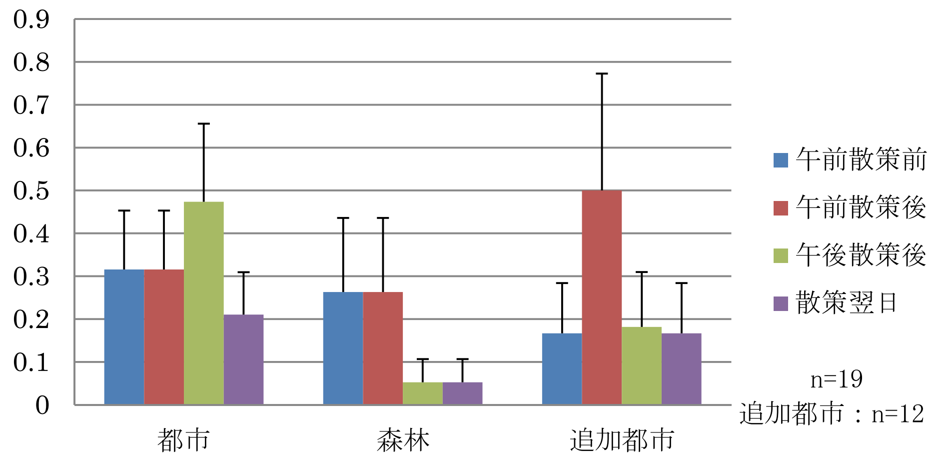
I 群（活力の低下）について森林散策による影響はなかったが、一方、午後の都市散策後に有意に増加した（図 27）。



*: $p<0.05$、**: $p<0.01$、午前散策前との比較、対応のある t 検定（両側）

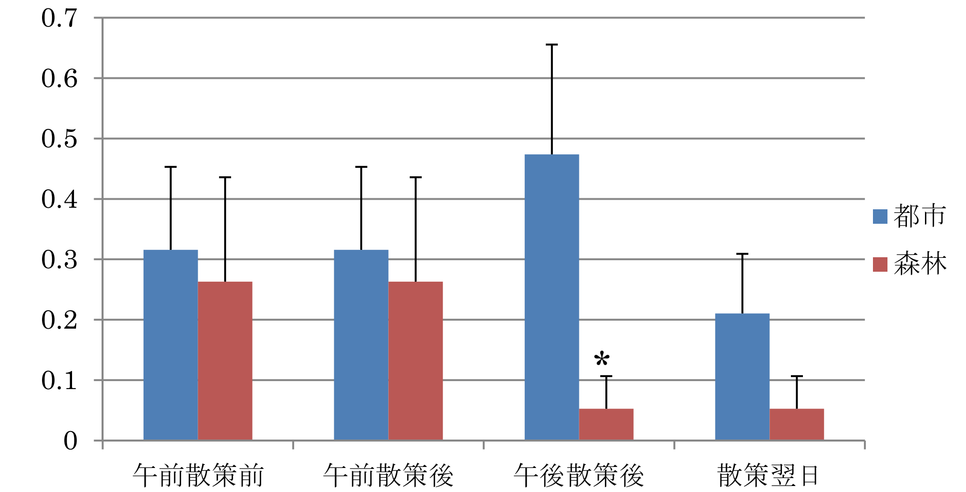
II 群（気力の低下）について両散策前後に有意な変化が認められなかったが（図 28）、都市散策と比較して午後の森林散策後に有意に低下したことから森林散策による改善効果が認められた（図 29）。

図28.　自覚症状（Ⅱ群　気力の低下）
（平均値+標準誤差）



対応のある t 検定（両側）

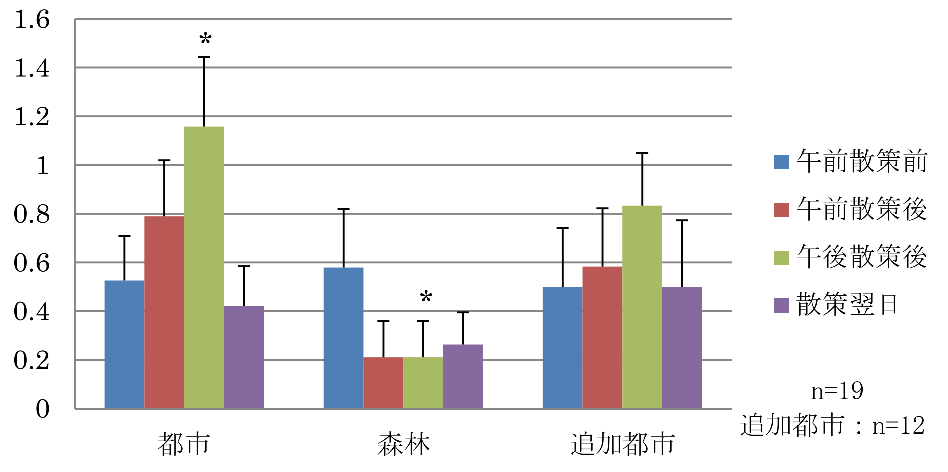
図29.　自覚症状（II群　気力の低下）　（平均値+標準誤差）



*：p<0.05, 都市との比較、対応のある t 検定（両側）

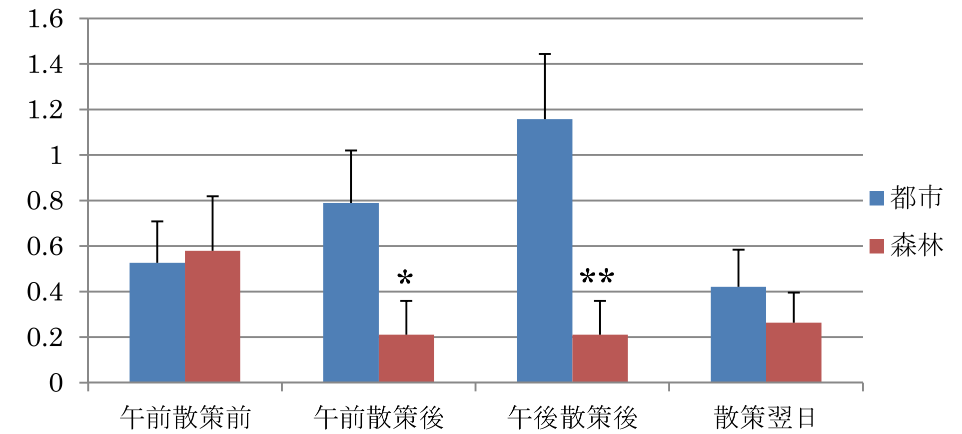
Ⅲ群（身体違和感）について午後の森林散策後に有意に低下したが、一方、午後の都市散策後に有意に増加した（図 30）。さらに都市散策と比較して午前と午後の森林散策後に有意に低下したことから森林散策による改善効果が認められた（図 31)。

図30.　自覚症状（Ⅲ群　身体違和感）
（平均値+標準誤差）



*: p<0.05、午前散策前との比較、対応のある t 検定（両側）

図31.　自覚症状（III群　身体違和感）（平均値+標準誤差）



*：p<0.05, **:p<0.01, 都市との比較、対応のある t 検定（両側）

9）森林浴による脂質代謝、糖代謝などへの影響

両散策とも脂質代謝指標（中性脂肪、総コレステロール、LDL-コレステロール、 HDL-コレステロール）、糖代謝指標（空腹血糖値、空腹ｲﾝｽﾘ値、Hb-A1c）、赤血球数、ヘモグロビン濃度、白血球数、白血球分画、血小板数及び高感度 CRP などに対する影響が認められなかった（表 5）。

表 5.　血液検査結果（平均±標準偏差）

検査項目		森林 (n=19)	8 月都市 (n=19)	9 月都市 (n=12)
中性脂肪 (50-130mg/dl)	散策前	135.6 ± 70.0	138.2 ± 76.6	160.8 ± 117.0
	散策後	144.2 ± 66.1	127.6 ± 55.1	248.3 ± 352.5
T-CHO (130-220mg/dl)	散策前	217.6 ± 42.8	221.6 ± 43.0	227.2 ± 52.0
	散策後	213.0 ± 39.0	212.4 ± 36.4	224.5 ± 59.0

HDL-C	散策前	60.1	±	14.9	61.2	±	15.3	58.5	±	15.3
(37-67mg/dl)	散策後	56.9	±	15.6	57.8	±	13.7	54.8	±	14.5
LDL-C	散策前	141.4	±	37.3	143.6	±	38.6	146.7	±	41.0
(≦120mg/dl)	散策後	137.1	±	36.0	138.1	±	32.5	140.8	±	41.5
CRP	散策前	0.2	±	0.7	0.1	±	0.1	0.1	±	0.1
(<0.30mg/dl)	散策後	0.1	±	0.3	0.1	±	0.1	0.1	±	0.1
空腹ｲﾝｽﾘﾝ	散策前	5.8	±	2.1	7.6	±	7.7	6.7	±	3.2
(5-10μU/ml)	散策後	6.1	±	3.5	6.9	±	6.2	7.5	±	4.2
空腹血糖	散策前	97.7	±	11.9	97.8	±	11.0	104.3	±	10.8
(60-120mg/dl)	散策後	95.9	±	10.9	96.7	±	11.9	99.6	±	10.5
Hb-A1cN	散策前	5.7	±	0.4	5.7	±	0.4	5.7	±	0.4
（4.6-6.2%）	散策後	5.7	±	0.4	5.7	±	0.4	5.7	±	0.4
白血球数	散策前	57.9	±	12.8	59.3	±	13.1	68.5	±	16.6
(35.9-96.4×10^2/μl)	散策後	59.0	±	15.2	57.2	±	12.2	67.1	±	20.5
赤血球数	散策前	496.2	±	45.4	496.9	±	41.6	499.9	±	46.7
(400-552×10^4/μl)	散策後	493.8	±	40.8	491.4	±	42.8	494.4	±	39.2
血色素量	散策前	15.3	±	1.0	15.4	±	0.9	15.5	±	1.3
（13.2-17.2g/dl）	散策後	15.3	±	1.0	15.2	±	1.0	15.5	±	1.1
ﾍﾏﾄｸﾘｯﾄ	散策前	44.6	±	2.8	44.5	±	2.5	45.4	±	3.1
（40.4-51.1%）	散策後	44.4	±	2.2	44.2	±	2.6	44.9	±	2.8
血小板数	散策前	22.1	±	4.0	22.5	±	4.1	23.2	±	3.5
(14.8-33.9×10^4/μl)	散策後	22.5	±	4.5	21.8	±	3.9	23.5	±	4.0
MCV	散策前	90.1	±	3.8	89.9	±	3.9	90.9	±	3.8
（85.6-102.5fl）	散策後	90.2	±	4.0	90.3	±	4.0	91.1	±	3.9
MCH	散策前	31.0	±	1.3	31.0	±	1.3	31.1	±	1.4
（28.2-34.4pg）	散策後	31.0	±	1.3	31.0	±	1.4	31.3	±	1.4
MCHC	散策前	34.4	±	0.8	34.5	±	0.8	34.2	±	1.0
（31.8-34.8g/dl）	散策後	34.3	±	0.8	34.3	±	0.9	34.4	±	0.8
好中球	散策前	57.5	±	7.0	57.5	±	7.0	59.9	±	6.6
(41.2-74.7%)	散策後	57.3	±	7.9	57.9	±	6.1	61.6	±	8.2
リンパ球	散策前	32.8	±	7.1	33.8	±	5.9	31.0	±	6.4
(21.2-51.0%)	散策後	33.6	±	8.0	33.3	±	5.9	29.6	±	7.8
単球	散策前	6.0	±	1.5	5.3	±	1.1	5.7	±	1.4
(3.1-6.0%)	散策後	5.5	±	1.7	5.4	±	1.3	5.3	±	1.3
好酸球	散策前	3.0	±	2.0	2.9	±	2.0	3.0	±	1.5
（0.2-6.4%）	散策後	3.1	±	2.3	2.9	±	2.0	3.0	±	1.3
好塩基球	散策前	0.6	±	0.4	0.5	±	0.3	0.5	±	0.3
(0.2-1.8%)	散策後	0.5	±	0.3	0.5	±	0.3	0.5	±	0.3
好中球数	散策前	33.4	±	9.0	34.4	±	9.9	41.4	±	12.6
	散策後	34.3	±	11.5	33.3	±	8.8	42.4	±	18.7

RDW-SD （38.8-50.0fl）	散策前	43.0 ± 2.5	43.0 ± 2.6	43.7 ± 2.6
	散策後	43.0 ± 2.6	43.2 ± 2.6	43.8 ± 2.5
RDW-CV （11.5-13.8%）	散策前	13.1 ± 0.5	13.2 ± 0.5	13.2 ± 0.5
	散策後	13.1 ± 0.5	13.2 ± 0.5	13.2 ± 0.4
P-DW	散策前	11.2 ± 1.1	11.2 ± 1.0	11.0 ± 0.9
	散策後	11.0 ± 1.1	11.2 ± 1.1	11.4 ± 1.1
MPV	散策前	10.1 ± 0.6	10.2 ± 0.5	10.0 ± 0.4
	散策後	10.1 ± 0.5	10.1 ± 0.5	10.2 ± 0.5
P-LCR 18.9-46.7%	散策前	25.0 ± 5.0	25.4 ± 4.2	24.4 ± 3.4
	散策後	25.1 ± 4.4	25.2 ± 4.5	25.8 ± 4.0

T-CHO：総コレステロール
HDL-C: HDL コレステロール
LDL-C: LDL コレステロール
CRP: C 反応性蛋白
RDW（red cell distribution width)： 赤血球容積粒度分布幅
MCV：平均赤血球容積
MCH：平均赤血球へモグロビン量
MCHC：平均赤血球へモグロビン濃度
P-DW：血小板分布幅
MPV：平均血小板容積
P-LCR：大型血小板比率

10）結論

結論として悪天候（雨、低気温）にもかかわらず、森林浴は、都市散策と比較して中高年男性被験者に以下の効果を示した。

① 脈拍数を有意に減少させる。
② POMS 検査では活気を有意に上昇させ、緊張・不安、抑うつ・落ち込み、疲労、混乱の自覚症状を有意に減少させる。
③ 自覚症状調査ではⅡ群（気力の低下）と III 群（身体違和感）に改善効果が認められた。
④ ストレスホルモンである尿中ドーパミンの変化に良い影響を与えた。
⑤ 血中アディポネクチンの変化に良い影響を与えた。
⑥ 総じて心理的・生理的リラックス効果が認められた。

3.参考文献

Hozawa A, Kuriyama S, Shimazu T, Ohmori-Matsuda K, Tsuji I. Seasonal variation in home blood pressure measurements and relation to outside temperature in Japan. Clin Exp Hypertens. 2011;33(3):153-8.

Jansen PM, Leineweber MJ, Thien T.The effect of a change in ambient temperature on blood pressure in normotensives. J Hum Hypertens. 2001;15(2):113-7.

Shimamoto, K.; Ando, K.; Fujita, T.; Hasebe, N.; Higaki, J.;, Horiuchi, M.; Imai, Y.; Imaizumi, T.; Ishimitsu, T.; Ito, M.; *et al*. The Japanese Society of Hypertension Guidelines for the Management of Hypertension (JSH 2014). Hypertens Res. 2014, 37, 253-390.

Woodhouse PR, Khaw KT, Plummer M. Seasonal variation of blood pressure and its relationship to ambient temperature in an elderly population. J Hypertens. 1993;11(11):1267-74.

Zhang X, Zhang S, Wang C, Wang B, Guo P. Effects of moderate strength cold air exposure on blood pressure and biochemical indicators among cardiovascular and cerebrovascular patients. Int J Environ Res Public Health. 2014;11(3):2472-87.

4.研究メンバー

李卿（研究代表、日本医科大学准教授・医師、国際自然・森林医学副会長・事務局長）
川田智之（日本医科大学教授・医師）
大塚俊昭（日本医科大学准教授・医師）
小林麻衣子（日本医科大学研究技術員）
久米田 茂喜（長野県立木曽病院名誉院長、国際自然・森林医学会専門医）
宮崎良文（千葉大学環境健康フィールド科学センター教授、国際自然・森林医学副会長）
宋チョロン（千葉大学環境健康フィールド科学センター助教）
香川隆英（国立研究開発法人 森林総合研究所室長）
池井晴美（国立研究開発法人 森林総合研究所研究員）
落合博子（国立病院機構東京医療センター形成外科医長、国際自然・森林医学会専門医）
落合俊也（㈱森林・環境建築研究所所長　国際自然・森林医学会会員）
今井通子（医師、医学博士、国際自然・森林医学会長）
王志玉（医学博士、中外製薬株式会社 薬事監査部臨床監査役）
趙東威（医学博士、日本医科大学助教）
田上正男（長野県上松町）
見浦崇（長野県上松町）

5.学会・講演会発表リスト

① 李卿. 森林セラピーの健康増進効果. かわさき市民アカデミー講座、2015. 12. 10, 川崎.

② Qing Li. Forest Medicine: Effects of forest environment on human health. 2nd annual meeting of World Outstanding Medical Doctors Association, 2016.1.8-10, Beijing, China.

③ Qing Li, Maiko Kobayashi, Shigeyoshi Kumeda, Hiroko Ochiai, Toshiya Ochiai, Takashi Miura, Takahide Kagawa, Michiko Imai, Toshiaki Otsuka, Tomoyuki Kawada. Effects of Forest Bathing on Cardiovascular and Metabolic Parameters in Middle-Aged Males. 18th International Conference on Modern Medicine and Alternative Medicine, January 12-13, 2016, Zurich, CH Switzerland.

④ Qing Li. Forest Medicine: Effects of forest environment on human health. The international symposium on multidisciplinary approach of forest healing, January 28th, 2016, Chungbuk National University, Republic of Korea.

⑤ 李卿. Natural Capitalsと健康価値創造：森林医学理論の実証と社会的事業への展開, 第５回健康価値創造研究会講演，2016.2.26，順天堂大学医学部.

⑥ 李卿. 森林セラピーの健康増進効果. 宍粟市森林セラピー講演会. 2016.3.2，神戸.

6.学会発表論文(18th International Conference on Modern Medicine and Alternative Medicine)（次頁）

Effects of Forest Bathing on Cardiovascular and Metabolic Parameters in Middle-Aged Males

Qing Li, Maiko Kobayashi , Shigeyoshi Kumeda, Hiroko Ochiai, Toshiya Ochiai, Takashi Miura, Takahide Kagawa, Michiko Imai, Toshiaki Otsuka, Tomoyuki Kawada

Abstract—In the present study, we investigated the effects of a forest bathing program on cardiovascular and metabolic parameters. Nineteen healthy male subjects (mean age: 51.3 ± 8.8 years) were selected after obtaining informed consent. These subjects took day trips to a forest park named Akasawa Shizen Kyuyourin, Agematsu, Nagano Prefecture (situated in central Japan), and to an urban area of Nagano Prefecture as a control in August 2015. On both trips, they walked 2.6 km for 80 min each in the morning and afternoon on Saturdays. Blood and urine were sampled in the morning before and after each trip. Cardiovascular and metabolic parameters were measured. Blood pressure and pulse rate were measured by an ambulatory automatic blood pressure monitor. The Japanese version of the profile of mood states (POMS) test was conducted before, during and after the trips. Ambient temperature and humidity were monitoring during the trips.

The forest bathing program significantly reduced pulse rate, and significantly increased the score for vigor and decreased the scores for depression, fatigue, and confusion in the POMS test. The levels of urinary noradrenaline and dopamine after forest bathing were significantly lower than those after urban area walking, suggesting the relaxing effect of the forest bathing program. The level of adiponectin in serum after the forest bathing program was significantly greater than that after urban area walking. There was no significant difference in blood pressure between forest and urban area trips during the trips.

Keywords—Ambient temperature, blood pressure, forest bathing, forest therapy, human health, POMS, Pulse rate.

I. INTRODUCTION

THE forest environment has long been enjoyed for its quiet atmosphere, beautiful scenery, calm climate, pleasant aromas, and clean fresh air. Researchers in Japan have tried to find preventive effects against lifestyle-related diseases from forests and have proposed a new concept called “forest bathing”. What is forest bathing? In Japan, a forest bathing is a short leisurely visit to a forest, called “Shinrin-yoku” in Japanese, which is similar in effect to natural aromatherapy, for the purpose of relaxation. “Shinrin" means forest and "yoku” means bathing in Japanese [1], [2]. Since forests occupy 67% of the land in Japan, forest bathing is easily accessible in Japan. Forest bathing as a recognized relaxation and/or stress management activity and a method of preventing diseases and promoting health is becoming a focus of public attention in Japan [2].

We previously found that forest therapy enhances human natural killer (NK) activity by increasing the number of NK cells and intracellular levels of anti-cancer proteins, such as perforin, granulysin, and granzymes in both male and female subjects [1]-[5]. The increased NK activity has been shown to last for more than 30 days after a trip [3], [4]. This suggests that if people take a forest therapy once a month, they may be able to maintain a higher level of NK activity. It is very important in the perspective of preventive medicine. Conversely, taking an urban trip has not been shown to increase human NK activity, numbers of NK cells, or the expression of the selected intracellular perforin, granulysin, and granzymes A/B, indicating that increased NK activity during a forest therapy is not due to the trip itself, but due to the forest environments [3]. Moreover, we also found that forest bathing significantly reduced blood pressure by reducing sympathetic nerve activity and urinary adrenaline, noradrenaline and dopamine levels and significantly increased serum adiponectin and dehydroepiandrosterone sulfate (DHEA-S) levels in male subjects [6].

II. SUBJECTS AND METHODS

In the present study, we investigated the effects of forest therapy on blood pressure and pulse rate during walking by an ambulatory automatic blood pressure monitor and other cardiovascular and metabolic parameters in middle age male subjects. Nineteen healthy male subjects, who ranged in age from 40-69 years (mean±SD: 51.3±8.8), were selected for the present study. Information about the subjects gathered from a self-administered questionnaire that asked about cigarette smoking, alcohol consumption, eating breakfast, sleeping hours, working hours, physical exercise, nutritional balance, and mental stress have been reported previously [6], [7]. Written informed consent was obtained from all subjects after a full explanation of the study procedures. None of the subjects had any symptoms of disease, used drugs that might have affected the results, or were taking any medication at the time of the study. The Ethics Committees of the Nippon Medical School and Nagano Prefectural Kiso Hospital approved this study.

The subjects took day trips to a forest park named Akasawa Shizen Kyuyourin (Akasawa Natural Recreation Forest), Agematsu, Nagano Prefecture (situated in central Japan) (Fig. 1) and to an urban area of Nagano Prefecture as a control (Fig. 2) in August 2015. On both trips, they walked 2.6 km for 80 min in the morning (11:00-12:20) and afternoon (13:40-15:00) on Saturdays. Blood and urine were sampled in the morning before and after each trip. Cardiovascular and metabolic parameters were measured. Blood pressure and pulse rate were measured by an ambulatory automatic blood pressure monitor at the same time every 20 min during each trip, and on the next morning after each trip. The Japanese version of the profile of mood states (POMS) test was conducted before, during and after the trips. Ambient temperature and humidity were monitoring during the trips.

Fig. 1 Forest bathing

Fig. 2 Urban area walking

III. RESULTS AND DISCUSSION

The maximum and average temperatures were 32.7°C and 31.2±0.7°C during the morning, 37.5°C and 33.2±1.4°C during the afternoon, respectively, in the urban area environment, whereas in the forest environment, the maximum and average temperatures were 20.4°C and 19.1±0.5°C during the morning, 20.7°C and 19.4±0.4°C during the afternoon, respectively. The average temperature in urban area was higher than that of forest by 12.1-13.8°C and the maximum temperature in urban area was higher than that of forest by 16.8°C.

As shown in Fig. 3, the forest therapy significantly reduced the pulse rate during 11:00-12:20 and 14:00-15:00, suggesting the relaxing effect of forest therapy program. We previously also found that a forest therapy program significantly reduced the pulse rate in middle aged males [8] and females [9].

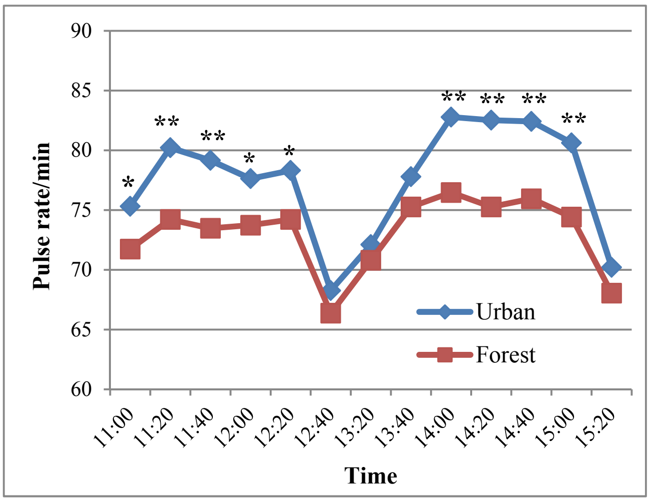
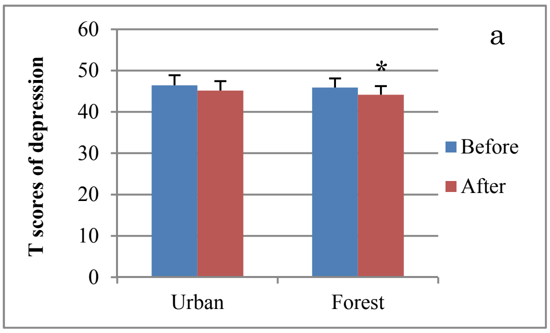
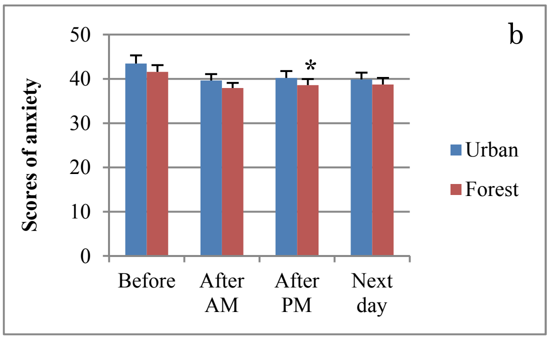


Fig. 3 Forest bathing program significantly reduces the pulse rate in male subjects. *: p<0.05, **: p<0.01, forest vs urban by paired t-test (n=19)

As shown in Fig. 4, the forest therapy significantly increased the score for vigor and decreased the scores for depression, fatigue, and confusion in the POMS test, whereas urban area walking significantly increased the score for fatigue and decreased the score for vigor, suggesting the relaxing effect of forest therapy program.





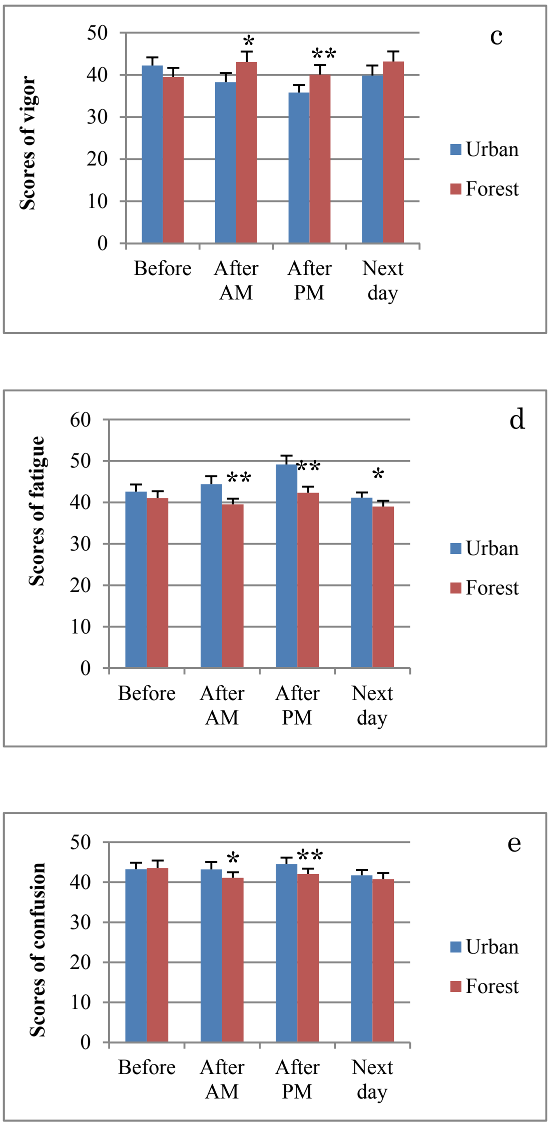


Fig. 4 Effect of forest bathing on the T scores of depression (a), anxiety (b), vigor (c), fatigue (d), and confusion (e) in the POMS test in male subjects (*: $p<0.05$, **: $p<0.01$, vs urban, by paired t-test (Mean+SE, n=19), After AM: after walking on the morning, After PM: after walking on the afternoon

Both trips significantly reduced the level of urinary noradrenaline and the level of urinary noradrenaline after forest therapy was significantly lower than that after urban walking (Fig. 5). Although there was no significant different between the before and after forest walking, the urinary adrenaline level trends toward decrease after the forest walking (Fig. 6). The urinary dopamine level after forest therapy was significantly lower than that after the urban area walking; however, there was no difference in baseline (before the trips), suggesting that forest therapy reduced the level of urinary dopamine (Fig. 7). It has been reported that sympathetic nerve activity can be determined by measuring the levels of urinary adrenaline, noradrenaline, and/or dopamine [10]. These findings suggest that forest therapy significantly reduced sympathetic nerve activity and increased parasympathetic nerve activity compared to performing the same activities in an urban environment. We previously found that forest therapy significantly reduced the levels of urinary adrenaline, noradrenaline and dopamine in both male and female subjects [3]-[6].

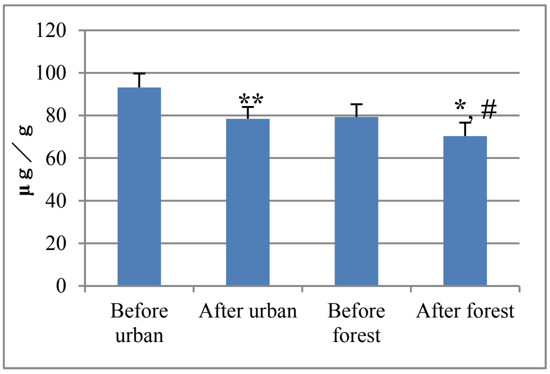


Fig. 5 Effect of forest bathing on the level of urinary noradrenaline in male subjects (**: p<0.01, vs before urban, *: p<0.05, vs before forest, #: p<0.05, vs after urban by paired t-test (Mean+SE, n=19))

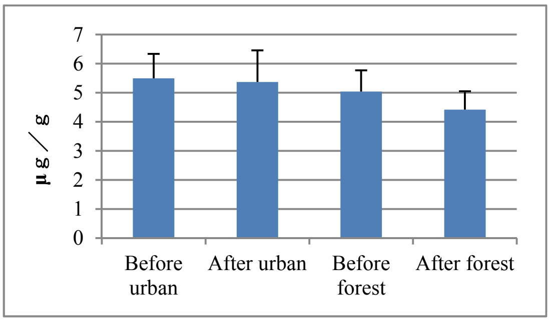


Fig. 6 Effect of forest bathing on the level of urinary adrenaline in male subjects (Mean+SE, n=19)

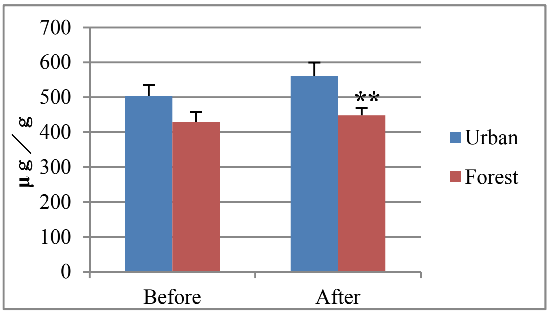


Fig. 7 Effect of forest bathing on the level of urinary dopamine in male subjects (**: p<0.01, vs urban, by paired t-test (Mean+SE, n=19))

As shown in Fig. 8, the level of adiponectin in serum after forest therapy was significantly greater than that after urban area walking; however, there was no difference in baseline (before the trips), suggesting that forest therapy increased the level of adiponectin in serum. Adiponectin is a serum protein hormone that is specifically produced by adipose tissue. Studies have shown that lower than normal blood adiponectin concentrations are associated with several metabolic disorders, including obesity, type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome [11]. We previously also found that forest therapy significantly increased serum adiponectin level in male subjects [6].

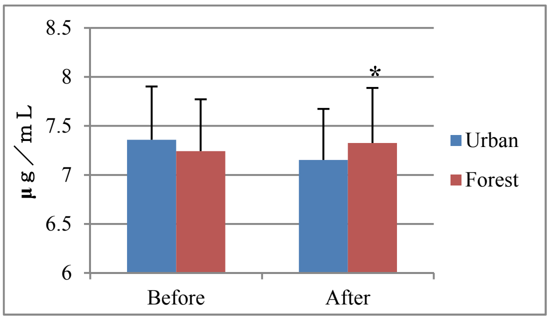


Fig. 8 Effect of forest bathing program on the level of adiponectin in male subjects (*: $p<0.05$, vs urban by paired t-test (Mean+SE, n=19))

As shown in Fig. 9, there was no significant difference in blood pressure between the forest and urban area walking during the trips because of the big difference in ambient temperature between the forest (lower temperature) and urban area (higher temperature) environments.

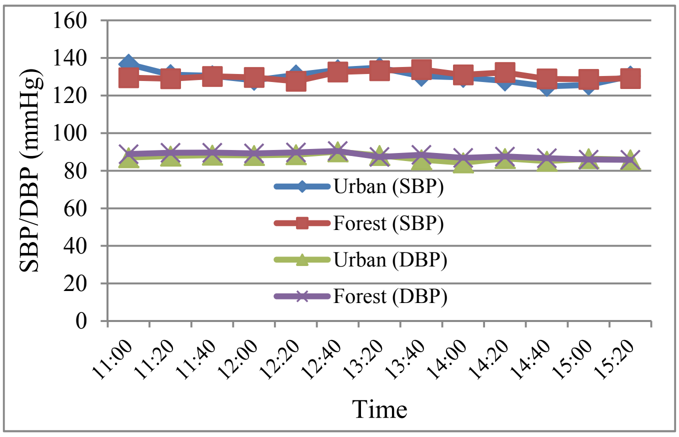


Fig. 9 Effect of forest bathing on blood pressure level in male subjects (n=19)

It has been reported that higher ambient temperature reduces blood pressure, whereas lower ambient temperature raises blood pressure [12]-[14]. Moreover, [12] reported that the blood pressures of elderly people may be inversely related to the ambient temperature and that after adjustment for confounding seasonal effects, a 1 degree C decrease in living-room temperature was associated with rises of 1.3 mmHg in SBP and 0.6 mmHg in DBP. Based on the background mentioned above, the blood pressure levels of subjects should be higher in forest than in urban area because of the lower temperature in the forest and the higher temperature in the urban area; however, the blood pressure levels of subjects in the forest were almost the same as those in the urban area, suggesting that forest environment prevented the rising of blood pressure from the effect of the lower temperature. In other words, the forest bathing contributed to the control of blood pressure and had a beneficial effect on the blood pressure. Further studies should be conducted under the same ambient temperatures in forest and urban area. In fact, we previously found that forest therapy significantly reduces blood pressure by reducing sympathetic nerve activity and urinary adrenaline, noradrenaline and dopamine levels, in which ambient temperature in forest was almost the same as that in urban area [6].

Neither walking in the forest nor walking in the urban area affected the levels of triglycerides, total Cho, LDL-Cho, HDL-Cho, insulin, HbA1c, or hs-CRP in serum, or blood glucose. Both trips also had no effect on the numbers of WBC, RBC, PLT, lymphocytes, granulocytes, or monocytes or the Hb concentration in the peripheral blood.

IV. Conclusions

Our study indicated that forest bathing produced a significant

(1) decrease in pulse rate,
(2) decreases in the level of urinary dopamine,
(3) increase in the level of adiponectin in serum,
(4) decreases in negative moods such as tension–anxiety, depression, fatigue and confusion in the POMS test and
(5) increase in feelings of vigor in middle-aged males.

Taken together, the forest bathing program induced significant physiological and psychological relaxation. These findings clarified the physiological and psychological effects of the forest therapy program and suggested a possibility of clinical use.

Acknowledgments

This study was conducted as a research project from the Vehicle Racing Commemorative Foundation of Japan.

References

[1] Li Q, Morimoto K, Nakadai A, Inagaki H, Katsumata M, Shimizu T, Hirata Y, Hirata K, Suzuki H, Miyazaki Y, Kagawa T, Koyama Y, Ohira T, Takayama N, Krensky AM, Kawada T. Forest bathing enhances human natural killer activity and expression of anti-cancer proteins. Int J Immunopathol Pharmacol. 2007, 20(S 2): 3-8.
[2] Li Q. Forest Medicine. In: Li Q (ed): Forest Medicine. Nova Science Publishers, Inc., NY, USA, pp.1-316, 2012.
[3] Li Q, Morimoto K, Kobayashi M, Inagaki H, Katsumata M, Hirata Y, Hirata K, Suzuki H, Li YJ, Wakayama Y, Kawada T, Park BJ, Ohira T, Matsui N, Kagawa T, Miyazaki Y, Krensky AM.

Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. Int J Immunopathol Pharmacol. 2008; 21: 117-128.

[4] Li Q, Morimoto K, Kobayashi M, Inagaki H, Katsumata M, Hirata Y, Hirata K, Shimizu T, Li YJ, Wakayama Y, Kawada T, Ohira T, Takayama N, Kagawa T, Miyazaki Y. A forest bathing trip increases human natural killer activity and expression of anti-cancer proteins in female subjects. J Biol Regul Homeost Agents. 2008; 22, 45-55.

[5] Li Q, Kobayashi M, Inagaki H, Hirata Y, Hirata K, Li YJ, Shimizu T, Suzuki H, Wakayama Y, Katsumata M, Kawada T, Ohira T, Matsui N, Kagawa T. A day trip to a forest park increases human natural killer activity and the expression of anti-cancer proteins in male subjects. J Biol Regul Homeost Agents. 2010; 24: 157-165.

[6] Li Q, Otsuka T, Kobayashi M, Wakayama Y, Inagaki H, Katsumata M, Hirata Y, Li Y, Hirata K, Shimizu T, Suzuki H, Kawada T, Kagawa T. Acute effects of walking in forest environments on cardiovascular and metabolic parameters. Eur J Appl Physiol. 2011;111(11):2845-53.

[7] Li Q, Morimoto K, Nakadai A, Qu T, Matsushima H, Katsumata M, Shimizu T, Inagaki H, Hirata Y, Hirata K, Kawada T, Lu Y, Nakayama K, Krensky AM. Healthy lifestyles are associated with higher levels of perforin, granulysin and granzymes A/B-expressing cells in peripheral blood lymphocytes. Prev Med. 2007; 44: 117-123.

[8] Song C, Ikei H, Kobayashi M, Miura T, Taue M, Kagawa T, Li Q, Kumeda S, Imai M, Miyazaki Y. Effect of forest walking on autonomic nervous system activity in middle-aged hypertensive individuals: a pilot study. Int J Environ Res Public Health. 2015; 12(3):2687-99.

[9] Ochiai H, Ikei H, Song C, Kobayashi M, Miura T, Kagawa T, Li Q, Kumeda S, Imai M, Miyazaki Y. Physiological and Psychological Effects of a Forest Therapy Program on Middle-Aged Females. Int J Environ Res Public Health. 2015; 12(12), 15222-15232.

[10] Frankenhaeuser M. Experimental approach to the study of catecholamines and emotion. In: Levi L, editor. Emotions, Their Parameters and Measurement. New York, Raven Press, pp. 209, 1975.

[11] Simpson KA, Singh MA. Effects of exercise on adiponectin: a systematic review. Obesity. 2008; 16: 241–256.

[12] Woodhouse PR, Khaw KT, Plummer M. Seasonal variation of blood pressure and its relationship to ambient temperature in an elderly population. J Hypertens. 1993;11(11):1267-74.

[13] Jansen PM, Leineweber MJ, Thien T.The effect of a change in ambient temperature on blood pressure in normotensives. J Hum Hypertens. 2001; 15(2):113-7.

[14] Zhang X, Zhang S, Wang C, Wang B, Guo P. Effects of moderate strength cold air exposure on blood pressure and biochemical indicators among cardiovascular and cerebrovascular patients. Int J Environ Res Public Health. 2014; 11(3):2472-87.

おわりに

公益財団法人　車両競技公益資金記念財団による“公益の増進に係る諸問題の解決・改善を目的とする調査及び研究事業の中で、平成 25 年度から平成 27 年度まで行った「国民の健康増進を目的とした森林セラピーによる予防医学的効果に関する調査研究事業」が終了いたしました。

内容は、被験者を要したフィールド実験であり、振り返ると調査は都市部、森林空間内共に戸外での作業も多く、近年特に顕在化した異常気象はじめ、自然現象・事象とのすり合わせを余儀なくされる場面もありました。

但し、平成 25、26 年度を担当された、千葉大学環境健康フィールド科学センター副センター長　宮崎良文教授、及び 27 年度担当の李卿　日本医科大学　医学部 医学科 衛生学公衆衛生学教室准教授共に、一例を挙げますと、2013 年に英国政府森林委員会が作成した「Mindfulness Practice in Woods and Forests：An Evidence Review」では、「Forest Bathing - “Sinrin－Yoku”」項目はじめ、報告書全体の中での引用論文の 10%以上は彼らの論文であるなど、日本のみならず国際的に「森林医学」を牽引されてこられた方々のリーダシップによるチームでしたので、安心、安全、確実性は担保出来ました。

さらに、フィールドとして使用した長野県では、県立木曽病院（名誉医院長　久米田茂喜先生）上松町（田上正男町長）その他地元の方々による多大な御貢献もあり、本事業は成功裡に終結出来たと考えられます。

すでに、この事業による成果は、International Journal of Environmental Research and Public Health 12(12)：15222-15232、その他、多数の論文として関連各紙に掲載済みです。
(http://www7b.biglobe.ne.jp/~infom/index.html)

現在、森林は、大気・淡水循環、気候緩和、砂漠化防止、生物多様性維持、その他多岐に渡るその機能が地球環境保護、保全分野で語られがちですが、豊かで整備の行き届いた森林がヒトに与える予防医学的効果の発見は、エコツーリズムだけではなく、エコでヘルシーなツーリズムとして発展することで、地元経済に活力を与えます。主に日本からの医科学的検証論文等を支えとし、確実となったこのツーリズムは諸外国でも注目され始めました。本調査研究が今後、地球環境維持と共に人間の健康維持・増進にとっても必ず必須である事がさらなる国際的な普及、波及効果の一助となる事を祈念し、おわりの言葉といたします。

平成２８年３月

森林浴による健康増進等に関する調査研究委員会
委 員 長　　今 井 通 子

[禁無断転載]
平成 28 年 3 月発行
平成 25 年度～平成 27 年度森林浴による健康増進等に関する調査研究報告書

発　行　　公益財団法人　車両競技公益資金記念財団
東京都文京区本郷 3-22-5
住友不動産本郷ビル 8 階
電話 03-5844-3070(代表)　　http://www.vecof.or.jp/
発行者　横　山　和　夫
印　刷　㈱サンワ

印刷 28.3.300